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U S ARMY NATICK LABORATORIES

TECHNICAL REPORT

ES-13

A METHOD FOR PREDICTING THE PROBABLE FREQUENCY OF OCCURRENCE OF DAILY MAXIMUM TEMPERATURES FROM SUMMARIZED DATA

EARTH SCIENCES DIVISION

AUGUST 1964

NATICK, MASSACHUSETTS

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(2) the mean daily maximum
(3) the mean daily minimum
(4) the length of record

Values on the nomograph have been determined by a detailed study of the frequency occurrence of daily maxima through a 10-year period for May, July and September at twelve representative stations. The method readily lends itself to machine processing.

At the end of the report is an extra copy of both the nomograph and the associated table, for easy withdrawal and use in doing prediction problems.

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2. Meteorological parameters
3. Nomographs
4. Diurnal variation
5. Probability
6. Periodic variations
I. Lackey, Earl E.
II. Title
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[redacted] ARMY NATICK LAB[redacted]S.,
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EARTH SCIENCES DIVISION

Technical Report
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by Earl E. Lackey, [redacted]

General Environments Laboratory

Project Reference:
1K025001A129

August 1964

FOREWORD

Activities and efficiency of Army personnel and the adequacy of Army materiel are often conditioned by the maximum ambient temperatures that may be encountered. In general, it is not enough to know the absolute maximum that has occurred through a series of years. It is more significant to know how frequently given critically high temperatures may be expected. Since daily high temperature frequency tabulations are not as a rule available, it is desirable to devise a method for predicting these high temperature frequencies from available temperature summaries. The following study presents a method whereby the frequency of specified high temperatures may be predicted with considerable confidence when the only temperature items available are: (1) the absolute maximum temperature, (2) the mean daily maximum, (3) the mean daily minimum, and (4) the length of record.

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Earth Sciences Division

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Scientific Director

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Colonel, QMC
Commanding

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ABSTRACT

The frequency and distribution of daily maximum temperatures for any given "summer" month (May-September in northern hemisphere) may be predicted with a considerable degree of confidence when only summarized data are available by use of a multiple nomograph. The nomograph and associated table represent 45 converted mean daily maximum temperatures, having values from 36 to 80, each of which is associated with a unique numerical pattern of converted predictive temperature values. The converted mean daily maximum temperature may be computed from the following four items usually found in climatic summaries:

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Values on the nomograph have been determined by a detailed study of the frequency occurrence of daily maxima through a 10-year period for May, July and September at twelve representative stations. The method readily lends itself to machine processing.

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A METHOD FOR PREDICTING THE PROBABLE FREQUENCY OF OCCURRENCE
OF DAILY MAXIMUM TEMPERATURES FROM SUMMARIZED DATA

Introduction

A method is presented here for predicting daily maximum temperature and frequencies for any given summer month from four items of summarized data, namely:

the absolute maximum (AbMx)* for the month
the mean daily maximum (MDMx)
the mean daily minimum (MDMi)
the length of the record.

The uniqueness of the method is the way in which four items in a summary record may be used to reveal the pattern of asymmetry of the frequency and distribution of daily maximum temperatures for any given warm-season month (Fig. 2 and Table III). The method does not require the use of mathematical models, but depends upon forty-five frequency patterns, determined empirically, each of which is identified by the asymmetrical position of the mean daily maximum (MDMx) between the absolute maximum (AbMx), and the mean daily minimum (MDMi) when the temperatures are all converted to a 100-unit scale.**

PART I - COVERAGE AND PROCESSING

1. Records used - area and time coverage

For purposes of this study, the daily maximum temperatures (DMx) for three "summer"*** months (May, July and September, 1946-1955) from twelve representative weather stations in the United States underscored in Figure 1 were used -- 36 records in all. Temperature data from the underscored stations were frequency tabulated by the U.S. Air Weather Service, Data Control Unit. The records from the other stations marked in Figure 1 were used to test the reliability of the method.

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*See Abbreviations and Glossary, Appendix A.

**Conversion to the 100-unit scale is explained in connection with Table I. Also see references 4 and 5.

***In this report a "summer month" is considered one of the 5 or 6 warmer months of the year. Also, all temperatures are in Fahrenheit.

LOCATION OF STATIONS USED IN CONSTRUCTING AND TESTING THE MULTIPLE NOMOGRAPH

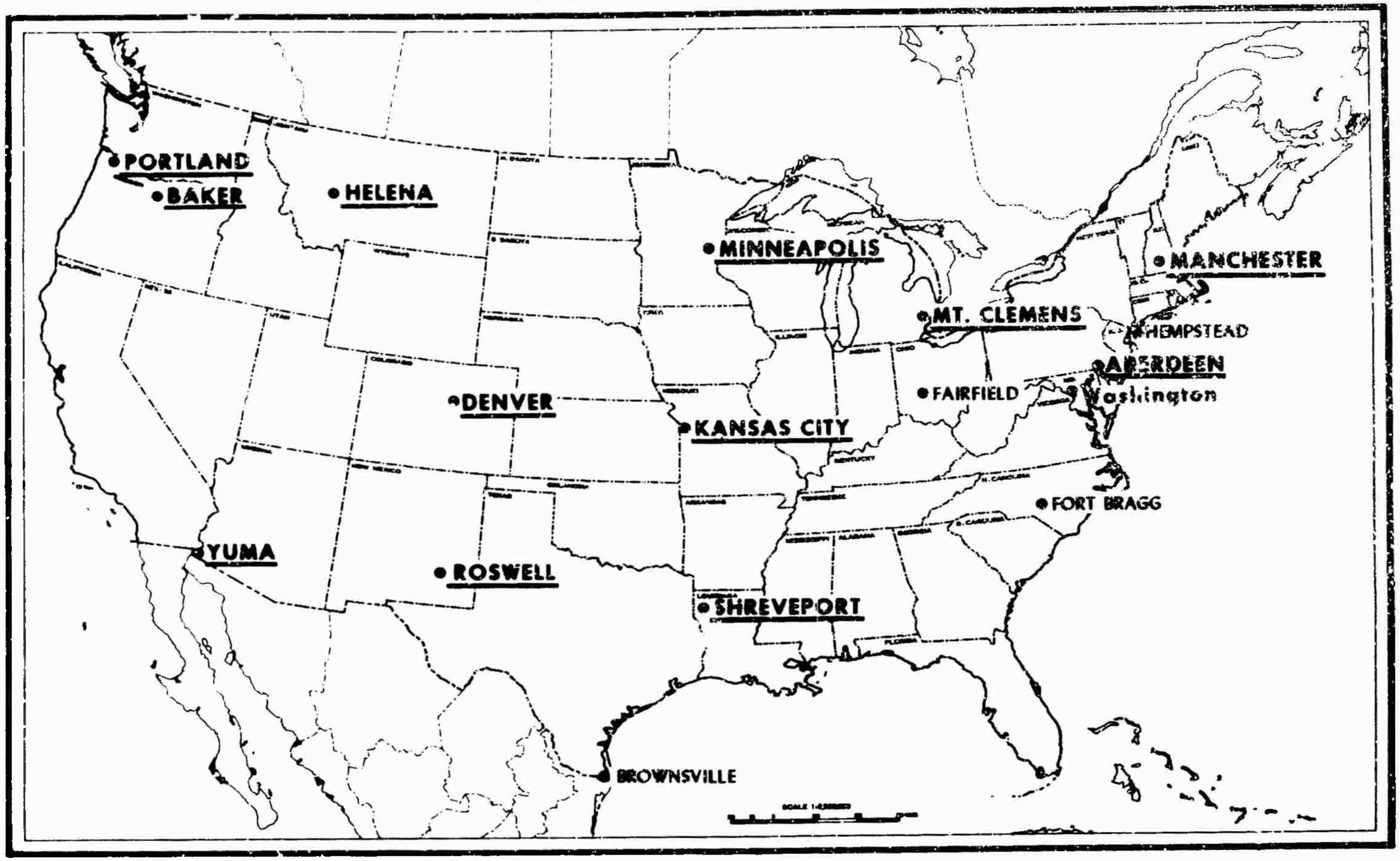


Figure 1

2. Compiling and tabulating the data

The tabulated data for the 36 months were assembled into tables similar to the one for May at Aberdeen, Maryland, Table I. It should be noted that the Essential Temperature Data in columns 1, 2, and 3, line c (95°F, 74°F and 53°F) are the only temperatures needed to assess the probable temperature that will be equaled or exceeded through the indicated number of years up to 100.

However, the Frequency Data on the same line (83 F, 85 F, etc., to 95 F) for 36 months at the other stations (3 different months, 12 stations) were needed to construct the nomographic device featured in this study. An understanding of Table I can greatly help in the discussion that follows.

3. Converting conventional data to the 100-unit scale

Conventional temperature values (Fahrenheit or centigrade)* cannot be used directly on the nomograph. It is adapted only to the use of "converted" values, that is, values that have been changed from conventional measures (Fahrenheit or centigrade) to a 100-unit scale. The predicting is done in converted scale values, which are then converted back to conventional (F. or C.) measures. For example, the Essential Data for Aberdeen, Maryland, were assembled as given in Table I, columns 1, 2, 3, line c. Essential Data are:

(1) 10-year Absolute Maximum (AbMx) 95°F
10-year Mean Daily Maximum (MDMx) 74°F
10-year Mean Daily Minimum (MDMi) 53°F

(2) Under Frequency Data (line c, columns 5 - 10) are given the 10-year frequency occurrence of daily maxima (°F) for six different time intervals, e.g.,

83°F daily maxima occurred an average of 5 days in every May (5/31)
85°F " " " " " " 3 " " " " (3/31)
89°F " " " " " " 1 day " " " (1/31)
93°F " " " " " " 1 " " 3 Mays (1/93)
94°F " " " " " " 1 " " 5 Mays (1/155)
95°F " " " " " " 1 " "10 Mays (1/310)

*Note: Fahrenheit values are used exclusively in the problems in this report.

TABLE I. ABERDEEN, MARYLAND, MAY: SAMPLE OF THE PROCEDURE IN CONSTRUCTING A MULTIPLE NOMOGRAPH FOR PREDICTING THE FREQUENCY AND LEVELS OF DAILY MAXIMUM TEMPERATURES. (See Appendix A for glossary and abbreviations)

Nature of Items	Essential Data (10-Yr Record)			(Lines)	Frequency Data (10-Yr Record)					
				a b	5/31 16.1%	3/31 9.7%	1/31 3.2%	1/93 1.1%	1/155 .64%	1/310 .32%
Recorded Temps °F	95 AbMx	74 MDMx	53 MDMi	c	83	85	89	93	94	95
Subtract MDMi (53°F)	53	53	53	d	53	53	53	53	53	53
Reduced Temps (RFT) Line c minus MDMi (53)	42 RAbMx	21 RMDMx	0 RMDMi	e	30	32	36	40	41	42
					-----	-----	-----RFT	-----	-----	-----
Converted Temps (CFT) 100-Unit Scale	100 CAbMx	50* CMDMx	0 CMDMi	f	71	76	86*	95	98	100
					-----	-----	-----CFT	-----	-----	-----
Predicted Temps Using Table III or Nomograph				g	83	86	90	92	93	95
					-----	-----	-----FPT	-----	-----	-----
(Columns)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)

Explanation

Line a. Ratio of temperature of given number of days to total days involved, e.g., 5/31, or 5 May days in 31 (1 month)

b. Temperature of given number of days as a percentage of total days involved, e.g., 5/31 = 16.1% of the total

c. Actual maximum temperature occurring during the designated frequency interval, e.g., 5 days in 31 days (5/31), 83°F or above.

d. Subtract MDMi (53°F) for purposes of conversion.

e. Reduced temperatures (c - d).

f. Reduced temperatures converted to 100-unit scale. Values in e multiplied by 100; divided by RAbMx (42).

g. Temperatures in line g were predicted later by use of the Nomograph, Basic Section.

Comment: 35 other records (12 stations, 3 different months) were processed in like manner. The ratios in line a above are averages reduced from the 10-year record, e.g., 50/310=5/31, 30/310=3/31, 10/310=1/31, etc.

*CMDMx 50 and CFT 86 are listed in Table II (Aberdeen, May) along with 35 other paired values, and plotted on Fig. 2 (see stars) to construct the 1/31 predictive curve. Values in line f are Converted Frequency Temperatures (CFT) and become CPT values when generalized on the nomograph.

The Aberdeen record (in line c Table I) was converted to a 100-unit scale as follows:

(1) Reduce each value in line c by subtracting from it the MDMi, 53°F (line d). Thus in line e -

the Reduced	AbMx	becomes	42°F
"	"	MDMx	"	21°F
"	"	MDMi	"	0°F

(2) In order to convert to the 100-unit scale (line f), the reduced AbMx (42°F) or temperature range between the MDMi and AbMx, is changed to 100 and the MDMi (col. 3) becomes zero (0).

Now where do each of the other items (columns 5 through 10) in line e fit into the 100-unit scale? Multiply each by 100 and divide by 42. (Conversion formula: multiply by 100 and divide by the reduced AbMx.) Thus each Fahrenheit temperature in line e is proportional to its corresponding converted value (CFT) in the 100-unit scale in line f.

It should be noted here that CMDMx 50 (Column 2) is the key to the frequency distribution (converted scale) of daily maximum temperatures in May at Aberdeen, Maryland. However, it was found that from station to station and month to month the asymmetrical (skewed) position of the CMDMx ranges widely, in fact from 38 (Minneapolis in May) to 75 (Yuma in September) on the 100-unit scale (Table II, the two underscored CMDMx's).* In other words, the position of the CMDMx's between 0 and 100 on the converted scale is the measure of the asymmetry and furnishes the pattern of the distribution of daily maximum temperatures between the CAbMx (100) and the CMDMi (0).

4. Some assumptions basic to the method

a. The frequency distribution of Daily Maximum temperatures for the present and future are reliably related to temperature distribution of the past.

b. The asymmetrical position of the Mean Daily Maximum temperature between the Absolute Maximum and Mean Daily Minimum furnishes nearly 50 patterns of distribution, one of which may be found to be satisfactory for any station for any of 5 warm months.

c. The Mean Daily Maximum temperature for any station through 10 or more years is a near constant.

*By extrapolation, the range of CMDMx was extended downward to 36 and upward to 80. (See Fig. 2 and Table III)

TABLE II: PAIRED CONVERTED TEMPERATURE VALUES USED FOR THE CONSTRUCTION OF THE ONE DAY PER MONTH PREDICTION LINE (10 DAYS IN 310)

	CMDMx	CFT		CMDMx	CFT
Aberdeen, Md.			Kansas City, Mo.		
May	50*	86*	May	43	74
July	57	89	July	53	90
Sept	51	85	Sept	45	83
Shreveport, La.			Portland, Ore.		
May	66	93	May	43	80
July	61	91	July	48	85
Sept	58	88	Sept	47	88
Manchester, N.H.			Helena, Mont.		
May	48	70	May	49	86
July	60	87	July	64	93
Sept	53	91	Sept	50	90
Minneapolis, Minn.			Baker, Ore.		
May	<u>38</u>**	74	May	51	86
July	49	91	July	67	94
Sept	45	89	Sept	58	91
Roswell, N. Mex.			Denver, Col.		
May	66	88	May	53	87
July	73	90	July	66	86
Sept	60	87	Sept	67	94
Mt. Clemens, Mich.			Yuma, Ariz.		
May	43	89	May	62	88
July	52	85	July	71	89
Sept	43	80	Sept	<u>75</u>**	95

* According to a 10-May record (310 days, Table I), Aberdeen had a CMDMx temperature of 50, and 1 day in 31 (1/31) a Converted Frequency Temperature (CFT) of 86 or above, but below 95 (base of adjacent time interval, (1/93).

** Underlined numbers 38 and 75 represent the lowest and highest CMDMx for the 36 records (3 months at each of 12 stations).

Note: The CFT's became CPT's when generalized in the Nomograph and Table III.

Note: It must be pointed out here that 12 of these months have 30 days each, and 24 months have 31 days each. The Nomograph and Table III integrated the 36 records and proceed as if each month has 31 days. Of course this does not coincide with the facts. However, the error is assumed to be negligible.

d. The Mean Daily Minimum temperature for any station through 10 or more years is a near constant.

e. The Daily Maximum temperatures (DMx) through 10 or more years (e.g., 310 May days rearranged in numerical sequence) is an increasing variable, but with a decelerated trend corresponding to the trend of a series of daily maxima arranged in an ascending numerical sequence.

f. This trend may be discovered by plotting the ascending decelerated series on a skew-log probability scale, using data from 10-year records.

g. The Mean Daily Minimum is a near stable anchor from which to measure the oscillating extreme maxima.

h. Usually, summary temperature records provide the essential data for computing the CMDMx and for predicting daily maximum temperature frequencies through any required span of years.

i. Tests for the spread of CMDMx from the latitude of Singapore, Malaya, to Tanana, Alaska, gave results well within the 36 to 80 of CMDMx on the Nomograph.

PART II - NOMOGRAPH, BASIC SECTION

5. Constructing the Basic Section

As stated before, conventional temperature values (Fahrenheit or centigrade) cannot be used directly on the nomograph (Fig. 2) but must be converted to a 100-unit scale. (See Table I.) The July and September daily maximum temperature records at Aberdeen, Maryland, were processed in the same way as those for May (shown in Table I). Corresponding records (1946-1955) for the same months at eleven other stations in the United States (Fig. 1 underscored) were processed in the same manner - 36 records in all. The CMDMx's ranged from 38 to 75, each associated with a family of converted frequency temperatures (CFT). (For example, CMDMx 50 in Table I, line f is associated with the converted values in the same line.) These CFT's are converted values of DMx's which actually occurred within the given frequencies (line c, Table I).

The sloping 1/31 line of the nomograph was plotted as follows: The CMDMx 50 (Table I, line f) and the CFT 86 (Table I, line f, column 7) are the paired converted temperature values for Aberdeen, Maryland, for 1 day in each May (year), or 1/31. (These paired values are shown at the beginning of Table II.) There is a corresponding pair (CMDMx and CFT values) for each of the other 35 records, ranging from a low CMDMx of 38 (May at Minneapolis) to a high CMDMx of 75 (September at Yuma). Each of these 36 pairs (Table II) is plotted (stars) on the Nomograph Basic Section (Figure 2). The (curved) line on the nomograph for the frequency 10 days in 310 or an average of 1 day in 1 month, 1/31, is the visual "best fit" through

and among the 36 plotted stars. The shape and position of this curved line is influenced somewhat by that of the nine associated curved predictive lines in the Basic Secion, all of which are similarly derived and mutually adjusted. The generalized predictive curves are for frequencies ranging from 25 days in a given month (25/31) to 1 day in 310 days (1/310, straight line) of the same month (i.e., 1 day in 310 May days, or 10 years) -- 10 predictive lines in all in the Basic Section.

6. Predicting maximum temperature frequencies by use of the Nomograph, Basic Section

Let us now go back to Table I and find out how near the predicted maxima for May at Aberdeen, Maryland, come to actual occurrences. There are three steps in finding the predicted maxima from 10-year records (Basic or Extrapolated Section of the nomograph): 1) Find the CMDMx, 2) Find the CPT* for the required frequency, 3) Using the Reconversion Formula, reconvert the values to degrees Fahrenheit.

The CMDMx for May at Aberdeen is CMDMx 50 (see Table I).

CPT values are found as follows: If on the nomograph we follow the horizontal line corresponding to CMDMx 50 to its intersection with predictive line 5/31 (5 days in 1 May, or 1 year) and then follow this point of intersection to the top - the CPT scale - we get the CPT value of 72. Corresponding converted predictive temperatures for from 5 days in 1 year to 1 day in 10 years are found by the same method to be:

5/31, 72; 3/31, 79; 1/31, 87; 1/93, 93; 1/155, 96, and 1/310, 100.

The formula for reconversion for maximum 1-day temperature (°F) associated with given frequencies is:

Predicted DMx (°F): $\frac{\text{CPT (AbMx - MDMi)}}{100} + \text{MDMi}$ Formula (Reconversion)

(Substituting:)
Probable DMx, 5/31: $\frac{72\ (95F - 53F)}{100} + 53F = 83F$**

Probable DMx 3/31: $\frac{79\ (95 - 53)}{100} + 53 = 86F$

Probable DMx 1/31: $\frac{87\ (95 - 53)}{100} + 53 = 90F$

*Note that the CPT values were taken from the actual maximum temperature frequencies at 12 stations, whereas the CPT's are generalized values taken from the nomograph.
**See footnote c to Table I.

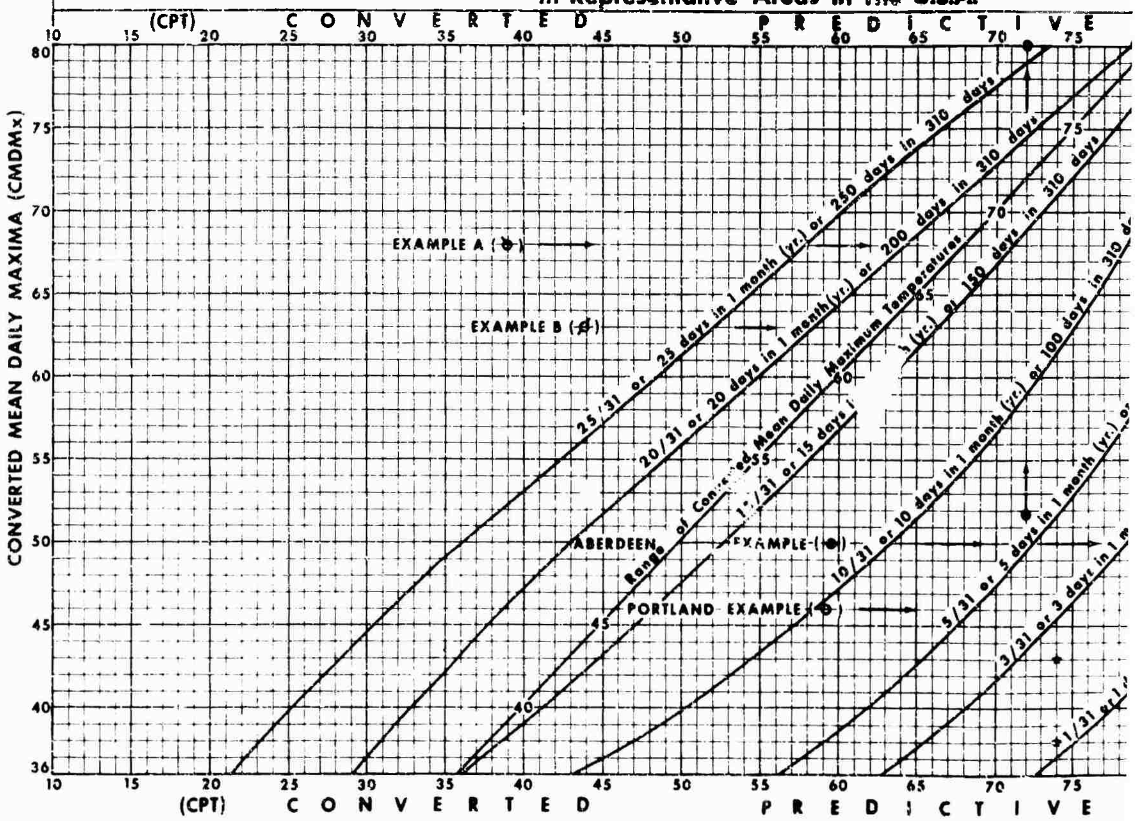
MULTIPLE NOMOGRAPH FOR PREDI

MAXIMUM TEMP

TO PREDICT FROM 10-YEA

Basic Section From 25 Days In a Given Month U

Constructed From Actual Frequency Distribution Of Daily Maxima At
In Representative Areas In The U.S.A.



Explanation of General Symbols:

☆ Stars in the Basic Section represent paired converted temperature values(CM

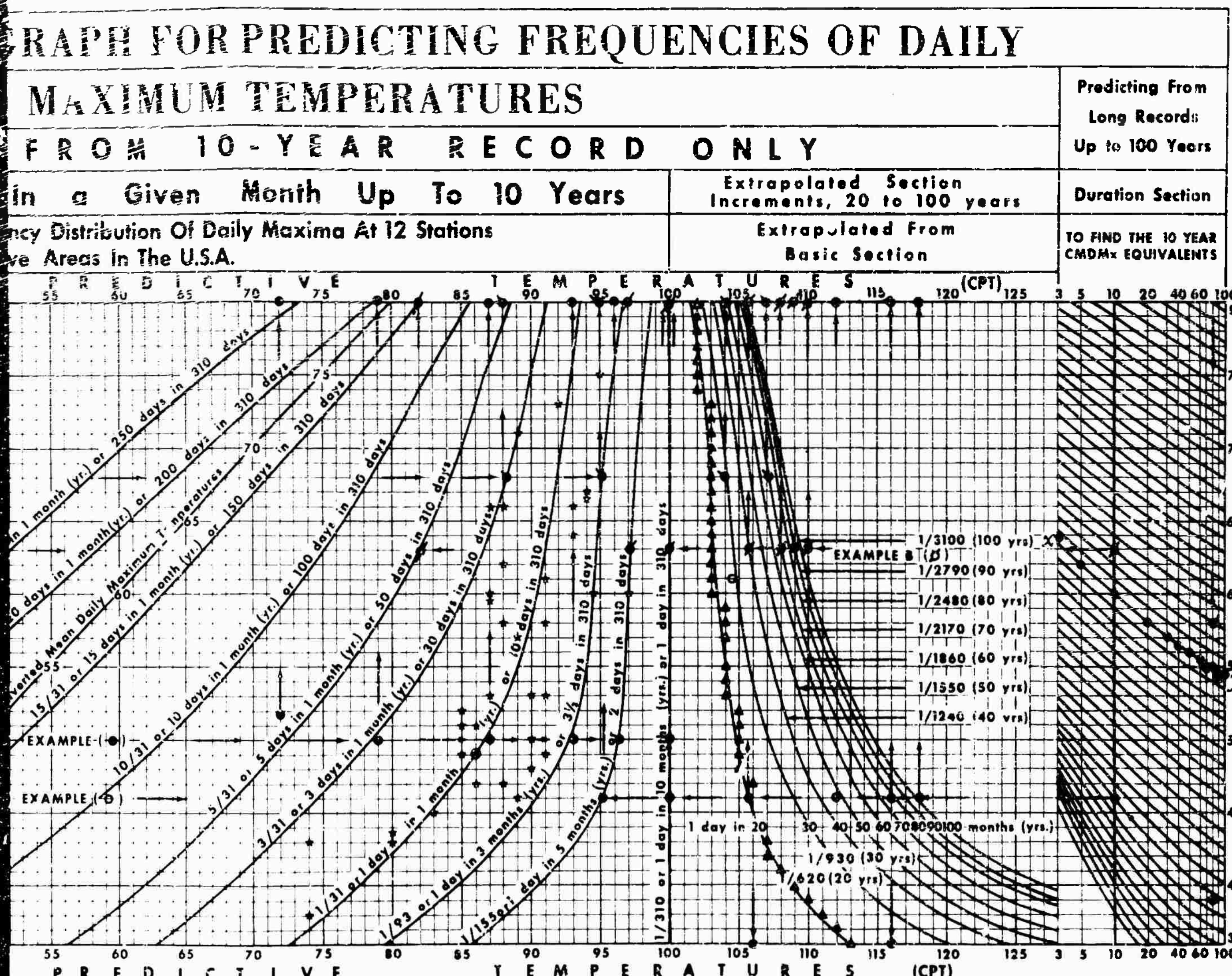
▲ Triangles in the Extrapolated Section represent CPT values extrapolated fro and used to construct the 1/620 prediction curved line.

● Dots in the "Duration" Section for line "xy", identifying the CMDMx 60 (on values to use in place of 12 different patterns of longer or shorter records(1

Examples A and B are discussed in Appendix C.

Examples Aberdeen and Portland are discussed in the text, Sections 6 and

Figure 2



nverted temperature values(CMDMx and associated CFT values, Table II) for the 1/31 curved prediction line.

nt CPT values extrapolated from the CPT trends in the 45 CMDMx predictive patterns in the Basic Section, urved line.

identifying the CMDMx 60 (on the 10-year vertical accentuated line) represent predictive pattern of CPT s of longer or shorter records(1/93 to 1/3100). See text, Section 12.

x C.

sed in the text, Sections 6 and 14, respectively.

Figure 2

2

Probable DMx 1/93: $\frac{93\ (95 - 53)}{100} + 53 = 92F$

Probable DMx 1/155: $\frac{96\ (95 - 53)}{100} + 53 = 93F$

Probable DMx 1/310: $\frac{100\ (95 - 53)}{100} + 53 = 95F$

It may be seen that the values predicted from the nomograph (line 9, Table I) for May at Aberdeen do not depart from the recorded (line c Table I) at any predictive level by more than 1F°. However, it should be expected that the CMDMx 50 pattern would always do as well on other summary 10-year (7 years to 14 years) records.

7. Constructing Table III Basic Section from Basic Section of the Nomograph (Fig.2) and its use

Each of the 10 predictive lines 25/31, 20/31, 15/31, etc., in the nomograph, Fig 2, Basic Section, crosses 45 horizontal CMDMx lines (36 to 80) making in all 450 fixed converted predictive temperature (CPT) values. (For example, note the six CPT values associated with CMDMx 50 in the preceding problem.) These 450 constant values (CPT's) are entered in Table III. They are the underlined, or principal, numbers in each cell. They are CPT's for predicting from 10-year records. (The other numbers in the cells are CMDMx identification factors, to be used if the record is longer or shorter than 10 years, and will be explained later.)

This table may be used instead of the Nomograph for predicting the probable daily maxima. For example: The CPT values associated with CMDMx 50 in the problem discussed above (72, 79, 87, etc.) are to be found on the table. Follow the numbers (underscored) on the horizontal CMDMx 50 line to the required time interval in the column heading at the top. Once you have the required CPT value, the procedure is the same; that is, you substitute the CPT values in the Reconversion Formula. See Appendix D, Example A, for the use of the table in predictions.

PART III - NOMOGRAPH, EXTRAPOLATED SECTION

Often it is desirable to know the daily maximum temperature probabilities for periods of time longer than 10 years. Thus, it became necessary to construct the Extrapolated Section of the Nomograph.

8. Theory and Use of a Skew-Log Probability Scale

It may be noted (Basic Section, Table III) that the converted predictive temperature values increase as the length of the record increases.

For example, for CMDMx 60 the converted values for 1, 3, 5 and 10 years are respectively, 90, 94, 97 and 100.* When these four values are plotted on a skew-log adjustable probability scale** (Fig. 3) and the straight line connecting them is prolonged to 1 day in 3100 (1/3100 or 0.032%) (100 Mays or 100 years) the decile-interval converted predictive temperature values (CPT) become:

103 for 20 Mays (1/620)	107 for 50 Mays (1/1550)
105 for 30 Mays (1/930)	108 for 60 Mays (1/1860)
106 for 40 Mays (1/1240)	110 for 100 Mays (1/3100)

9. Construction of Nomograph, Extrapolated Section

The process described in the preceding paragraphs of extrapolating the values of a 10-year record (specifically the associated CPT's of CMDMx 60) into a period longer or shorter than 10 years was repeated for each of the other 44 CMDMx patterns (36 to 80). The 44 triangles on the Extrapolated Section of the Nomograph furnished the "visual" pattern for the predictive line, 1 day in 20 Mays or years (620 May days, 1/620). The other predictive curved lines in the Extrapolated Section (1/930, 1/1240, 1/1550, etc., to 1/3100) were constructed in a similar manner (see curved lines on Nomograph, Extrapolated Section). As in the Basic Section, the shape and position of the curved predictive lines in the Extrapolated Section were influenced somewhat by the shape and position of the associated predictive lines, all of which were similarly derived and mutually adjusted. Thus was constructed from 36 monthly records at 12 stations a nomograph based on 10 years of tabulated monthly maximum temperature frequencies from which it is now possible from abbreviated records to predict the frequency of expected maximum temperatures for any summer month for 1, 3, 5, and 10 years, and also (Extrapolated Section) for decile yearly increments from 20 up to 100 years.***

10. Using the Nomograph: Predicting from a 10-Year Record, the Probable Maximum Temperatures for a Given Month from 1 to 100 Years

By use of the Nomograph (Fig. 2, Basic Section) maximum temperature predictions for Aberdeen were made for periods of 10 years or less (see

*See underscored values on CMDMX 60 line, Table III.

**The skew-log probability scale is a Gumbel Extreme probability scale superimposed on two-cycle logarithmic paper. Because of its flexibility, a curved line of distribution may be converted to a near straight line. See reference 4.

***The nomograph and Table III may be used also to predict the maximum temperatures to be expected for as many as 25 days per month (25/31).

TABLE III. TABULAR EQUIVALENT OF THE NOMOGRAPH

CMD M.		Constructed from 10-Years Actual Frequencies									Constructed by Extrapolation from 10-Year Frequency Records											CMD Mx
	Frequency in Days	25/31	20/31	15/31	10/31	5/31	3/31	1/31	1/93	1/155	1/310	1/620	1/930	1/1240	1/1550	1/1860	1/2170	1/2480	1/2790	1/3100	
	Frequency in %	80.6	64.5	48.4	32.3	16.1	9.68	3.22	1.075	.645	.323	.161	.108	.0805	.0645	.0538	.0461	.0403	.0358	.0323	
	Years of Record	1	1	1	1	1	1	1	3	5	10	20	30	40	50	60	70	80	90	100	
80		72	79	82	85 94	88 91	91 88	94 85	97 83	99 81	100 80	102 79	103 78	104 77	104 77	105 76	105 76	106 76	106 76	106 76	80
79		70	78	81	84 94	88 90	91 87	93 85	96 83	99 80	100 79	102 78	103 77	104 76	104 76	105 75	105 75	105 75	106 75	106 75	79
78		69	76	80	84 93	87 90	90 86	93 84	96 81	98 79	100 78	102 77	103 76	104 75	104 75	105 74	105 74	106 74	106 74	106 74	78
77		68	75	79	83 93	87 89	90 85	93 83	95 80	98 78	100 77	102 76	103 75	104 74	104 74	105 73	105 73	106 73	106 73	107 72	77
76		66	74	79	83 92	87 88	90 84	93 82	96 79	98 77	100 76	102 75	103 74	104 73	104 73	105 72	105 72	106 72	106 72	107 71	76
75		65	72	78	82 91	87 87	90 83	92 81	96 78	98 76	100 75	102 73	103 73	104 72	105 71	105 71	106 71	106 71	107 70	107 70	75
74		63	72	77	82 90	86 86	90 82	93 80	96 77	98 75	100 74	102 72	103 72	104 71	105 70	106 70	106 70	106 70	107 69	107 69	74
73		62	70	76	81 90	86 85	89 82	93 79	96 76	98 74	100 73	103 71	103 71	104 70	105 69	106 69	106 69	107 68	107 68	107 68	73
72		60	69	75	81 89	86 84	89 81	92 78	95 76	98 73	100 72	103 70	103 70	104 69	105 68	106 68	106 68	107 67	107 67	107 67	72
71		59	68	74	80 89	85 83	89 80	92 77	95 75	98 72	100 71	103 69	104 68	105 68	105 67	106 67	107 66	107 66	107 66	108 66	71
70		56	67	73	80 88	85 82	89 79	92 76	95 74	98 71	100 70	103 68	104 67	105 67	106 66	106 66	107 65	107 65	108 65	108 65	70
69		[illegible]	66	72	79 87	84 82	88 78	92 75	95 73	98 70	100 69	103 67	104 66	105 66	106 65	106 65	107 64	107 64	108 64	108 64	69
68		57	65	71	78 87	84 81	88 77	92 74	95 72	98 69	100 68	103 66	104 65	105 65	106 64	107 64	107 63	107 63	108 63	108 63	68
67		56	64	70	78 86	84 80	88 76	91 73	95 71	98 68	100 67	103 65	104 64	105 64	106 63	107 63	107 62	108 62	108 62	109 62	67
66		55	64	69	77 86	83 79	87 76	91 72	95 70	98 67	100 66	103 64	104 63	105 63	106 62	107 62	107 61	108 61	108 61	109 61	66
65		55	62	68	76 85	83 78	87 75	91 71	95 69	98 [illegible]	100 65	103 63	104 62	105 62	106 61	107 61	108 60	108 60	109 60	109 60	65
64		54	61	67	76 84	82 78	85 74	91 70	95 68	97 66	100 64	103 62	104 61	106 61	106 60	107 60	108 59	108 59	109 59	110 59	64
63		52	59	66	75 84	82 77	85 73	91 69	95 67	97 65	100 63	103 61	105 60	106 60	107 59	108 58	108 58	108 58	109 58	110 58	63
62		50	57	65	74 83	81 76	86 72	91 68	95 66	97 64	100 62	103 60	105 59	106 59	107 58	108 57	108 57	109 57	109 57	110 57	62
61		49	56	64	74 83	81 75	86 71	90 67	95 65	97 63	100 61	103 59	105 58	106 58	107 57	108 56	108 56	109 56	110 56	110 56	61
60		48	56	63	73 82	80 75	85 71	90 66	94 64	97 62	100 60	103 58	105 57	106 57	107 56	108 55	109 55	109 55	110 55	110 55	60
59		46	[illegible]	62	72 82	80 74	84 70	90 65	94 63	97 61	100 59	104 57	105 56	106 56	108 55	109 54	109 54	110 54	110 54	110 54	59
58		45	53	61	71 82	79 73	84 69	90 64	94 62	97 60	100 58	104 56	105 55	107 55	108 54	109 53	109 53	110 53	110 53	111 52	58
57		43	51	60	70 81	78 73	83 69	90 63	94 61	97 59	100 57	104 55	106 54	107 53	108 53	109 52	110 52	110 52	111 51	111 51	57
56		41	50	59	69 81	78 72	82 68	89 62	94 60	97 58	100 56	104 54	106 53	107 52	109 52	110 51	110 51	111 51	111 50	112 50	56
55		40	49	58	68 81	77 71	82 67	89 62	94 59	97 57	100 55	104 53	106 52	107 51	109 51	110 50	111 50	111 50	112 49	112 49	55
54		32	48	57	67 81	75 71	82 66	89 61	94 58	97 56	100 54	104 52	106 51	107 50	109 50	110 49	111 49	112 48	112 48	113 48	54

72	62	61	[illegible]	82 87	86 84	83 [illegible]	92 78	25 76	28 73	100 72	102 70	103 70	104 69	105 68	106 68	106 68	107 67	107 67	107 67	72
71	12	58	74	72 84	85 83	84 80	92 77	25 75	28 72	100 71	103 69	104 68	105 68	105 67	106 67	107 66	107 66	107 66	108 66	71
70	15	57	73	80 88	85 82	83 77	92 76	25 74	28 71	100 70	103 68	104 67	105 67	106 66	106 65	107 65	107 65	108 65	108 65	70
69	17	58	72	71 87	84 82	88 75	92 75	25 73	28 70	100 69	103 67	104 66	105 66	106 65	106 65	107 64	107 64	108 64	108 64	69
68	17	61	71	78 87	84 81	88 77	92 74	25 72	28 69	100 68	103 66	104 65	105 65	106 64	107 64	107 63	107 63	108 63	108 63	68
67	15	54	70	78 86	84 80	88 76	91 73	25 71	28 68	100 67	103 65	104 64	105 64	106 63	107 63	107 62	108 62	108 62	109 62	67
66	11	54	59	77 85	83 79	87 76	91 72	25 70	28 67	100 66	102 64	104 63	105 63	106 62	107 62	107 61	108 61	108 61	109 61	66
65	11	52	58	76 85	83 78	87 75	91 71	25 69	28 66	100 65	102 63	104 62	105 62	106 61	107 61	108 60	108 60	109 60	109 60	65
64	14	51	57	75 84	82 78	85 74	91 70	25 68	27 66	100 64	103 62	104 61	106 61	106 60	107 60	108 59	108 59	109 59	110 59	64
63	12	52	56	75 84	82 77	86 73	91 69	25 67	27 65	100 63	103 61	105 60	106 60	107 59	108 58	108 58	108 58	109 58	110 58	63
62	50	57	55	74 83	81 76	86 72	91 68	25 66	27 64	100 62	103 60	105 59	106 59	107 58	108 57	108 57	109 57	109 57	110 57	62
61	49	56	54	74 83	81 75	86 71	90 67	25 65	27 63	100 61	103 59	105 58	106 58	107 57	108 56	108 56	109 56	110 56	110 56	61
60	48	56	53	73 82	80 75	85 71	20 66	24 64	27 62	100 60	103 58	105 57	106 57	107 56	108 55	109 55	109 55	110 55	110 55	60
59	46	55	52	72 82	80 74	84 70	20 65	24 63	27 61	100 59	104 57	105 56	106 56	108 55	109 54	109 54	110 54	110 54	110 54	59
58	45	53	51	71 82	79 73	84 69	20 64	24 62	27 60	100 58	104 56	105 55	107 [illegible]	108 54	109 53	109 53	110 53	110 53	111 52	58
57	43	51	50	70 81	78 73	83 59	20 63	24 61	27 59	100 57	104 55	106 54	107 53	108 53	109 52	110 52	110 52	111 51	111 51	57
56	41	50	59	69 81	78 72	83 58	89 52	24 60	27 58	100 56	104 54	106 53	107 52	109 52	110 51	110 51	111 51	111 50	112 50	56
55	40	49	58	68 81	77 71	82 67	89 62	24 59	27 57	100 55	104 53	106 52	107 51	109 51	110 50	111 50	111 50	112 49	112 49	55
54	39	48	57	67 81	76 71	82 66	[illegible] 61	24 58	27 56	100 54	104 52	106 51	107 50	109 50	110 49	111 49	112 48	112 48	113 48	54
53	38	47	56	66 80	75 70	81 65	88 60	24 57	26 55	100 53	104 51	106 50	108 49	110 49	111 48	112 47	112 47	113 47	113 47	53
52	37	46	54	65 80	74 70	81 64	88 59	22 56	26 54	100 52	105 50	107 49	108 48	110 48	111 47	112 46	113 45	113 46	114 46	52
51	35	45	52	64 80	73 70	80 64	87 59	22 55	25 53	100 51	105 49	107 48	108 47	110 47	111 46	113 45	113 45	114 45	114 45	51
50	34	44	52	63 79	72 69	79 63	87 58	92 54	26 52	100 50	105 48	107 47	109 46	111 45	112 45	113 44	114 44	114 44	115 43	50
49	34	43	51	62 79	71 69	78 [illegible]	85 58	92 [illegible]	26 51	100 49	105 46	107 46	109 45	111 44	112 44	114 43	114 43	115 43	115 42	49
48	33	42	50	61 79	70 69	77 62	85 56	92 52	26 50	100 48	105 45	108 45	110 44	111 43	113 43	114 42	115 42	115 42	116 41	48
47	32	41	48	60 78	69 68	76 62	84 56	91 51	96 49	100 47	106 44	108 44	110 43	112 42	113 42	115 41	115 41	116 41	117 40	47
46	31	40	47	59 78	68 68	75 61	83 55	91 50	95 48	100 46	106 43	109 43	111 41	112 41	114 41	115 40	116 40	117 39	118 39	46
45	31	40	47	58 78	67 67	74 61	82 55	90 50	95 47	100 45	106 42	109 41	111 40	113 40	115 39	116 39	117 39	118 38	119 38	45
44	29	32	46	57 77	66 [illegible]	[illegible]	81 54	89 49	94 47	100 44	106 41	110 40	112 39	114 39	116 38	117 38	118 37	119 37	120 37	44
43	27	37	45	56 77	65 66	72 60	80 54	88 49	93 46	100 43	107 40	111 39	113 38	115 38	117 37	118 36	119 36	120 36	121 36	43
42	25	35	44	55 76	64 66	71 59	79 53	86 48	92 46	100 42	107 39	112 38	114 37	116 36	118 36	119 36	120 35	122 34	123 34	42
41	23	33	42	54 76	63 65	70 59	78 53	85 48	91 45	100 41	108 38	112 36	115 36	117 35	119 35	121 34	122 34	124 33	125 33	41
40	22	32	41	53 76	62 65	69 58	77 52	84 47	[illegible] 44	100 40	109 37	114 35	116 35	119 34	121 33	123 33	124 32	126 32	127 32	40
39	20	30	40	52 75	61 64	68 57	76 51	83 47	89 44	100 39	110 36	115 34	117 34	121 32	123 32	125 31	126 31	128 31	130 30	39
38	18	28	39	51 75	60 63	67 57	75 51	82 46	88 43	100 38	111 34	116 33	119 32	123 31	125 30	128 30	129 30	131 29	138 29	38
37	16	26	38	50 74	59 63	66 56	74 50	81 46	87 43	100 37	112 33	118 31	121 31	125 30	127 28	131 28	132 28	134 28	136 27	37
36	15	25	36	49 74	58 62	65 55	73 49	80 45	86 42	100 36	113 32	120 30	124 29	127 28	131 28	134 27	136 27	138 26	140 26	36

2

CMDMX 60 (10-YEAR RECORD) EXTRAPOLATED TO 100 YEARS (3100 JULY DAYS)

BY USE OF A SKEW - LOG PROBABILITY SCALE

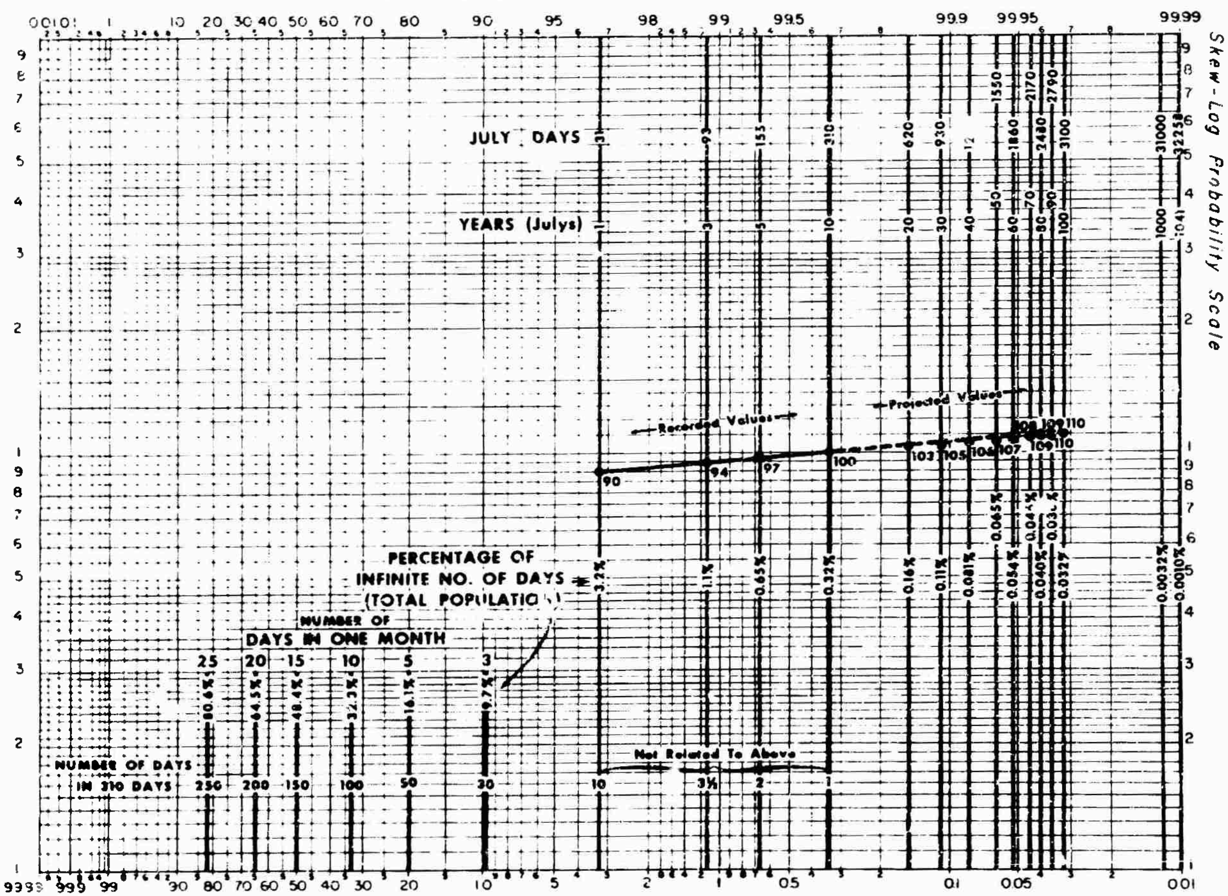


Figure 3

section 6 above). Now by use of the Extrapolated Section of the Nomograph, predictions up to 100 years may be made from the 10-year record.

For example, let us consider the above-mentioned Aberdeen-May pattern:

We have CMDMx 50 (Table I).

To find the CPT values: We follow CMDMx 50 on the Nomograph from the Basic Section, beyond the 100 CPT limit and into the Extrapolated Section. CMDMx 50 intersects the 20-year predictive curve (1 day in 620 May days) at a point which would indicate (according to the scale at the top of the graph) a CPT of 105. This and other CPT values of CMDMx 50 pattern, similarly found, are as follows:

20 yrs, <u>105</u>	30 yrs, <u>107</u>	40 yrs, <u>109</u>	50 yrs, <u>111</u>	60 yrs, <u>112</u>
70 yrs, <u>113</u>	80 yrs, <u>114</u>	90 yrs, <u>114</u>	100 yrs, <u>115</u>	

These values are reconverted to Fahrenheit by using the Reconversion Formula (Section 6 above). In this Formula, the maximum 1-day temperature associated with the required frequency is:

$$\frac{\text{CPT (AbMx - MDMi)}}{100} + \text{MDMi}$$

Substituting, for 1/620 $\quad \frac{105\ (95 - 53)}{100} + 53 = 97\text{F}$

Substituting, for 1/930 $\quad \frac{107\ (95 - 53)}{100} + 53 = 98\text{F}$

Thus the maximum temperature frequency probabilities for Aberdeen in May are:

1	May	day	in	20	years	(1/620 May days):	97F*
1	"	"	"	30	"	(1/930 May days):	98F
1	"	"	"	40	"	(1/1240 May days):	99F
1	"	"	"	50	"	(1/1550 May days):	100F
1	"	"	"	80	"	(1/2480 May days):	101F
1	"	"	"	100	"	(1/3100 May days):	101F

The 10-year summary record (AbMx, MDMx, MDMi) for any station for any summer month may be used for predictive purposes after the CMDMx pattern has been computed as in the Aberdeen example. For another illustration of the predictive techniques, see Appendix C, Example A.

*See footnote to Table I, line c.

11. Construction and Use of Table III, Extrapolated Section

There are about 400 constant values at the intersections of the horizontal CMDMx lines (36 to 80) and the nine sloping prediction lines in the Extrapolated Section of the nomograph. These CPT values are entered in Table III, Extrapolated Section, underscored numbers. Table III may be used instead of the Nomograph for predicting probable maximum temperatures and frequencies for any given summer month for periods of 15 to 100 years. The steps are the same as for predicting from the Basic Section (see Section 7 above), or for predicting from the nomograph: 1) Find the CMDMx 2) Find on the table (or Nomograph) the CPT for the required frequency 3) Use the Reconversion Formula to convert to °F. A complete example of this type problem is given in Appendix D, Example A.

PART IV - CONSTRUCTION OF THE NOMOGRAPH, "DURATION" SECTION

12. Derivation of Data for Constructing "Duration" Section of the Nomograph

It must be remembered that the CPT values (underscored numbers) of both the Basic and Extrapolated Sections of Table III are keyed exclusively to 10-year records and, therefore, Table III may be used for prediction of Daily Maximum Temperatures and Frequencies when the essential data (AbMx, MDMx and MDMi) are for approximately 10 years (8 to 14).

When the summarized data for processing come from records longer or shorter than 10 years, the "Duration" Section of the nomograph must be used to identify the 10-year equivalent pattern to substitute for the CMDMx for the longer or shorter period of record.

Every line in the "Duration" Section of the nomograph (vertical, horizontal and sloping) is keyed to the accentuated 10-year vertical line. The essential data for drawing the sloping lines in the "Duration" Section are the numbers (not underscored) in Table III. These values are computed as follows: It may be seen that daily maximum temperatures when arranged in a numerical sequence, become progressively higher with increased length of record, but at a decelerated rate. This is illustrated, for example, in Table III, where the CPT values (underscored numbers) associated with CMDMx 60 run as follows: 73, 80, 85, 90, 94, 97, 100, etc., to 110, respectively. Each of these values is keyed to the 100-unit scale with the CMDMx 60 and the 10-year basic record. However, this whole 10-year sequence of CPT's associated with CMDMx 60 may be converted into an equivalent 100-scale sequence corresponding proportionally to, for example, a 70-year record.

In this case, the CPT 109 (extrapolated 70-year prediction, based on 10-year records) becomes CPT 100 for an equivalent 70-year (record) CPT scale and the 10-year (record) CMDMx 60 becomes the 70-year (record) CMDMx 55.

$\left[(60 \text{ times } \frac{100}{109} = 55.046 \text{ or } 55 \text{ (rounded)} \right.$

See "55", (not underlined) CMDMx 60, 70-year column, Table III)]

In other words, the 70-year (record) CMDMx 55 becomes identified with the 10-year record CMDMx 60 pattern of converted prediction values. Other identification values in the same line associated with CMDMx 60 are (all not underlined numbers in Table III):*

for 3 years:	63.8	or 64**		for 50 years:	56.1	or 56
" 5 "	61.9	62		" 60 "	55.6	" 56
" 10 "	60.0	60		" 70 "	55.0	" 55
" 20 "	58.3	58		" 90 "	54.5	" 55
" 30 "	57.1	57		" 100 "	54.5	" 55
" 40 "	56.6	57				

There are 16 identification values for each CMDMx (36 to 80) - more than 700 such entries in Table III.

When the above-mentioned CMDMx 60 identification values are entered on the nomographic grid in the "Duration" Section of the Nomograph, they determine the smooth identification curve "x y". Similar curves were constructed for each of the other CMDMx's (36 to 80) from the associated values in Table III, i.e., the numbers not underlined. The CMDMx identification values for the numbers not underlined in Table III are each associated with a counterpart in the "Duration" Section of the Nomograph, and some one of these more than 700 CMDMx's is assumed to represent the pattern of summary temperature record (AbMx, MDMi and MDMx) of 3 years to 100 years for any summer month.

Since the "x y" line, ("Duration" section) representing the CMDMx for any length record from 3 years to 100 years, crosses the 10-year line (vertical, accentuated) at 60, it follows that the CPT values on CMDMx 60 may be used for predictive purposes for records running from CMDMx 55 to CMDMx 64 for any summer month from 3 years to 100 years.

For another example, it is evident that a 90-year record with a CMDMx 44 would use the 10-year (record) CMDMx 50 pattern of converted temperatures (CPT) for predictive purposes. (In the "Duration" Section of the nomograph, at the point where horizontal line CMDMx 44 crosses the 90-year vertical line, follow the nearest sloping line to where it crosses the 10-year vertical line: CMDMx: 50.) Each of the sloping lines in the "Duration" Section is designed to serve purposes similar to the marked "x y" line.

*The identification values for the numbers not underlined were computed in the same manner as the present CMDMx 55, Table III.

**Rounded.

To recapitulate: In order to make Table III more useful, the numerical CMDMx value at each intersection (sloping and horizontal lines) in the "Duration" section of the Nomograph is entered with its 10-year (record) associated CPT value (computed as shown earlier) in the 10-year prediction Table III (numbers not underlined). There are more than 700 such entries in Table III. Thus, the CMDMx 44 mentioned in the above paragraph may be found in the 90-year column (number, not underlined) associated with the 10-year-record CMDMx 50 and 10-year-record CPT 114 (the underlined number in the same cell). That is to say, the 90-year-record CPT is at least 1.14 times the 10-year-record CPT. Let us solve a specific problem.

13. Using Table III, including identification numbers CMDMx's (not underscored) for indicated lengths of record

Solution of problems involving record of more than 10 years can be done more easily by use of Table III than by the nomograph.*

Given: In May at Portland, Oregon, during a 78-year record:
AbMx: 99F MDMx: 68F MDMi: 48F

Required: What May day maximum temperature should be expected 1 day in -
20 yrs (1/620)? 50 yrs (1/1550)? 100 yrs (1/3100)? 5 yrs (1/155)?

Solution:

a. Find the 80-year (record) CMDMx

Formula: $$\text{CMDMx} = \frac{100\ (\text{MDMx} - \text{MDMi})}{\text{AbMx} - \text{MDMi}}$$

(Substituting:) $$\frac{100\ (68 - 48)}{99 - 48} = 39.2$$

b. Find the 10-yr (record) equivalent to CMDMx 39 in 80-yr column (Table III)

Method: Follow down the 80-year column of numbers not underlined to number 39, that is, the CMDMx for 80-year record. This is found on the CMDMx 45 line. Therefore CMDMx 45 10-yr pattern will be used for prediction. (Increasing the length of the record increased the AbMx but at a decelerated rate, thus changing the CMDMx pattern, 39 in one instance, 45 in the other.

*For another illustration, see Appendix D, Example B: Kansas City

c. Find the required CPT's, using the CMDMx 45 pattern

Method: Follow CMDMx 45 from left margin to each required time interval, as indicated in column heading at top. These CPT's are:

For 20 years, 106; For 50 years, 113; 100 years, 119; 5 years, 95

d. Find the 10-year (record) predicted Absolute Maximum

Formula: $$\frac{100\ (80\text{ yr AbMx} - 80\text{ yr MDMi})}{80\text{ yr CPT on CMDMx }45} + \text{MDMi}$$

(Note: Value in denominator above is in the 80-yr column, CMDMx 45 line of table. That is, the 80-yr AbMx is CPT 117 on the 10-yr table.)

Substituting: $$\frac{100\ (99F - 48F)}{117} + 48F = 92F$$

e. Reconvert CPT's in (c) to °F (using 92F as AbMx)

Formula (DMx associated with given frequencies:)

$$\frac{\text{CPT}\ (10\text{-yr AbMx} - 80\text{-yr MDMi})}{100} + \text{MDMi}$$

(Substituting CPT's from c above:)

Predicted 20-yr Mx $$\frac{106\ (92 - 48)}{100} + 48 = 95F$$

Predicted 50-yr Mx $$\frac{113\ (92 - 48)}{100} + 48 = 98F$$

Predicted 100-yr Mx $$\frac{119\ (92 - 48)}{100} + 48 = 100F$$

Predicted 5-yr Mx $$\frac{95\ (92 - 48)}{100} + 48 = 90F$$

When the constant values listed in Table III are entered on punch cards and directions according to the preceding formulas are given to a computing machine, processing of the data for the frequencies of expected daily maximum temperatures can be done quickly and accurately.

14. Using the "Duration" Section of the Nomograph for prediction

This example shows how to use the nomograph constructed from 10-year daily records to predict daily maximum probabilities from summary records of more than 10 years - in fact, from 3 years to 100. The problem is the same as the one for Portland using Table III, Section 13.

Given: In May at Portland, Oregon, during a 78-year record:
AbMx: 99F MDMx: 68F MDMi: 48F

Required: What May day maximum temperature should be expected 1 day in -
20 yrs (1/620)? 50 yrs (1/1550)? 80 yrs (1/2480)?
100 yrs (1/3100)? 5 yrs (1/155)?

Solution:

a. Find the 80-year CMDMx (for 78-year record).
This is 39.2 (see Section 13 above, part a of solution).

b. Find the 10-year equivalent CMDMx pattern.

Method: On the "Duration" section of nomograph, follow down the 80-year vertical line to CMDMx 39. Then follow the nearest sloping line left and upward to vertical line 10 years (accentuated). This is on horizontal line CMDMx 46.*

c. Find the required CPT values in the CMDMx 46 pattern. (See "Portland Example")

Method: Follow CMDMx 46 left to predicting sloping lines, 1/620, 1/1550, 1/2480, 1/3100, 1/155 (see arrows and circles). Thence, go upward to corresponding CPT values 106, 112, 116, 118, and 95, respectively.

d. Find the 10-year (1/310) expected May Maximum

Formula: $\dfrac{100\ (\text{80-yr AbMx} - \text{80-yr MDMi})}{\text{80-yr CPT on CMDMx 46}} + \text{MDMi}$

Substituting: $\dfrac{100\ (99F - 48F)}{116} + 48F = 92F$

*The Table value is CMDMx 45. The slight difference here is negligible and is to be expected. If the values in the Table and on the Nomograph were expressed with fractional exactness, the predictions would agree even more closely. In order to make serious differences in predictions the CMDMx's would need to differ by several units.

e. Reconverting CPT's in (c) using 92F as AbMx

Formula: Required Predictions:

$$\frac{\text{CPT (10-yr. AbMx - 80 yr. MDMi)}}{100} + \text{MDMi}$$

Substituting:

Prediction for 20-yr Mx $\quad \frac{106\ (92-48)}{100} + 48 = 95F$

Prediction for 50-yr Mx $\quad \frac{112\ (92-48)}{100} + 48 = 97F$

Prediction for 80-yr Mx $\quad \frac{116\ (92-48)}{100} + 48 = 99F$

Prediction for 100-yr Mx $\quad \frac{118\ (92-48)}{100} + 48 = 100F$

Prediction for 5-yr Mx $\quad \frac{95\ (92-48)}{100} + 48 = 90F$

PART V - TESTING THE RELIABILITY OF THE METHOD

15. Internal consistency

Tabulated actual temperature frequencies for a 10-year (10 May) record at Aberdeen are given in Table I, Frequency Data, line c. In line g are listed the corresponding temperatures and frequencies as predicted by use of the nomograph from the Essential Data in line c. This may be termed the internal consistency of the method. Predicted temperatures at each of the six frequency levels are within 1F° of the recorded. This test could be repeated for the 3 months (May, July and September) for each of the twelve stations.

16. Testing the method for a different month (August)

Tests similar to that for Aberdeen (May, July and September) were made for the month of August for four widely separated stations (Hempstead, N.Y., Fairfield, Ohio, Fort Bragg, N.C., and Brownsville, Tex., Fig 1). The results are shown in Table IV. It may be seen that the recorded temperature frequencies for August did not differ from the predicted at any of the seven frequency levels by more than 2F° (28 comparisons in all).

TABLE IV: RELIABILITY OF THE NOMOGRAPH
RECORDED AND PREDICTED FREQUENCIES FOR AUGUST COMPARED

Station		Essential Data			Frequency Data						
		Ab Mx	MD Mx	MD Mi	10/31 32.3%	5/31 16.1%	3/31 9.7%	1/31 3.23%	1/93 1.08%	1/155 0.645%	1/310 0.323%
Hempstead N.Y.	Recorded	97	81	64	84*	87	89	92*	96	97	97
	Predicted				85	88	91	93	95	96	97
Fairfield Ohio	Recorded	97	85	62	89	92	94	96	97	97	97
	Predicted				89	91	92	94	95	96	97
Fort Bragg N.C.	Recorded	101	83	68	91	94	95	97	98	100	101
	Predicted				93	95	96	98	99	100	101
Brownsville Texas	Recorded	101	92	76	94	95	96	97	99	100	101
	Predicted				92	94	96	98	99	100	101

*That is, the recorded temperature in August at Hempstead reached 84°F or above, but below 87°F (the next time interval) 100 August days in 10 years (310 days in all), or 32.3% of the time; 92°F, 10 August days in 310 days, or an average of 1 August day per month (1/31) for 3.23% of the time.

The temperatures at Hempstead, predicted from the Essential Data (97°, 81° and 64°), ran 1 or 2 degrees higher at the designated temperature levels, than the recorded.

See Formulas, Sections 3, 6 and 13 of this report.

17. Testing the method by use of extended records

Summarized records for longer than 10 years duration were found for five of the component stations shown in Figure 1. These were tabulated for May, July and September. Associated with the summarized data for each are the predictions at various time intervals from 1 to 100 years (Table V).

The first line for each month gives summarized data and seven tabulated frequency values of recorded daily maximum temperatures for 10 years only. The remainder of line 1, of course, is blank. The 16 frequency temperatures in each of the second, third and fourth lines for each month are all maxima predicted from the independent summarized data in the same lines.

The starred temperature in each line is the recorded maximum for the time (decade) intervals, in years, shown in the first numeral column (40, 61, 15, 67, 56, etc.). The first line for each month gives recorded maximum temperature frequencies, based on a 10-year record. The second, third and fourth lines of frequencies are predictions for the corresponding months, made from the summarized records. See formulas in Appendix D.

The problem of sampling is critical. In general, the longer the continuous record, the higher the Absolute Maximum temperature (AbMx) will be. (Baker, Oregon in July with 101, 102, 103 and Kansas City in September with 107, 108 and 109). However, if the given records are not continuous, or the longer records do not include the shorter ones, then the comparative predictions may appear erratic (Baker, Oregon in May). In the case of Baker in July, the predictions from different length records (10-, 40-, and 61-years) do not differ at any decile level by more than 2F° to 3F°, even though neither the 40- or 61-year records included the 10-year daily maximum record. Therefore, the predicted maxima from a short record may run higher than in the predictions from a longer record, e.g., Shreveport, La., in July.

In general, the 10-year maximum temperature predictions from the longer records were somewhat lower than the recorded 10-year maxima.

The conclusion, evidently, is that the essential summarized data should come from relatively long records if the predicted temperature frequencies are to have satisfactory reliability.

TABLE V. - CONSISTENCY OF PREDICTIONS FROM THREE DIFFERENT LENGTHS OF RECORD FOR EACH OF THREE MONTHS AT EACH OF FIVE STATIONS

Station	Record: Month	Record: Years	Summarized Data: Ab Mx	Summarized Data: MD Mx	Summarized Data: MD Mi	CMSk Temp. Patterns: Full Time	CMSk Temp. Patterns: 10-Year Equiv.	32.3 10/1	16.1 5/1	9.68 3/1	3.23 1/1	1.075 1/3	.645 1/5	.323 1/10	.161 1/20	.108 1/30	.081 1/40	.065 1/50	.054 1/60	.046 1/70	.040 1/80	.036 1/90	.032 1/100
								Predicted One-Day Maximum Temperature (F°) Frequency (1 day in Specified Years) From Different Periods of Record															
Baker, Oregon	May	10	94	67	38			73	79	82	86	89	91	94									
		10	94	67	38	52	52	74	79	83	87	90	93	94	97	98	99	100	100	101	101	101	102
		40	90	64	39	49	53	70	74	77	80	83	84	86	88	[illegible]	90	91	91	92	92	92	92
		61	91	65	39	50	55	71	75	78	81	83	85	86	88	89	89	90	91	91	91	[illegible]	92
	July	10	101	85	46			89	93	95	98	99	101	101									
		10	101	85	46	67	67	89	92	94	96	98	100	101	103	103	104	104	105	105	105	105	106
		40	102	82	51	[illegible]	63	87	91	92	95	97	98	99	100	101	102	102	103	103	103	103	104
		61	104	82	49	60	54	88	91	93	95	97	98	100	102	102	103	103	104	104	104	105	105
	Sept	10	99	71	36			81	87	93	94	95	97	99									
		10	95	71	35	56	56	81	86	89	93	95	97	99	102	103	103	105	105	105	106	106	107
		40	94	71	42	56	59	77	81	83	86	88	90	91	93	93	94	95	95	95	96	96	96
		61	94	71	41	52	57	78	82	85	89	90	92	94	96	97	97	98	99	99	99	100	100
Kansas City, Mo.	May	10	103	77	57			83	87	89	91	94	98	103									
		10	103	77	57	43	43	73	87	90	94	97	100	103	106	108	109	110	111	111	112	112	113
		15	95	77	55	55	57	80	85	87	89	91	92	93	95	95	96	96	97	97	97	98	98
		67	103	75	56	40	46	83	87	90	93	95	96	98	100	101	101	102	102	103	103	104	104
	July	10	111	93	72			97	102	103	107	109	110	111									
		10	111	93	72	54	54	98	102	104	107	109	110	111	113	113	114	115	115	116	116	116	116
		15	109	90	68	51	58	93	97	99	102	104	105	106	107	108	109	109	109	109	110	110	110
		67	112	92	71	51	56	99	102	104	105	107	108	109	110	111	111	111	111	112	112	112	112
	Sept	10	107	81	60			86	91	94	99	102	104	107									
		10	107	81	60	51	51	90	96	98	101	104	105	107	110	110	111	112	112	113	113	114	114
		15	108	81	58	46	49	89	93	96	100	103	104	106	108	109	110	111	112	113	113	113	113
		67	109	81	60	43	49	89	91	94	97	100	101	103	105	106	107	106	108	109	109	109	109
Portland, Oregon	May	10	95	69	49			75	81	84	86	92	94	95									
		10	95	69	49	43	43	76	79	82	86	89	92	95	98	100	101	102	103	103	104	104	105
		56	99	67	50	36	42	74	77	80	83	86	89	92	95	97	98	99	99	100	100	101	102
		78	99	67	48	37	44	73	76	79	83	86	87	91	94	95	96	97	98	98	99	99	100
	July	10	103	79	57			85	86	89	96	100	102	103									
		10	103	79	57	48	48	85	89	92	96	99	101	103	107	109	110	110	111	112	112	112	113
		56	104	78	58	43	48	83	87	90	93	96	97	99	101	102	103	104	104	105	105	105	106
		78	104	79	56	48	54	87	90	93	96	97	99	100	[illegible]	102	102	103	103	104	104	104	105
	Sept	10	97	74	54			78	83	86	92	94	95	97									
		10	97	74	54	47	47	80	84	87	90	93	95	97	100	101	101	102	103	103	103	104	104
		56	97	71	54	40	46	74	80	83	86	89	90	92	94	95	96	97	97	98	98	98	99
		78	102	72	52	40	46	77	81	84	88	91	93	95	96	95	100	110	101	101	102	102	103
Shreveport Louisiana	May	10	93	83	68			87	89	90	91	92	93	95									
		10	93	83	68	68	68	76	88	89	91	91	[illegible]	93	94	94	95	95	95	95	95	95	96
		56	101	83	64	51	55	87	91	92	94	96	97	98	99	100	100	101	101	101	101	101	102
		81	101	84	64	54	59	86	89	93	95	96	97	98	99	100	100	101	101	101	101	101	101
	July	10	105	93	73			95	97	99	102	103	104	105									
		10	105	93	73	63	63	97	99	101	102	103	104	105	107	107	107	108	108	108	108	108	108
		56	107	92	[illegible]	56	[illegible]	95	97	99	101	102	103	104	105	106	106	107	107	107	107	107	108
		81	107	93	74	58	63	96	98	100	101	103	103	104	105	106	106	106	106	106	107	107	107
	Sept	10	105	88	64			93	96	97	100	102	104	105									
		10	105	88	64	59	59	94	97	98	101	103	104	105	106	107	107	108	108	108	108	109	109
		56	105	87	67	53	58	92	95	96	99	100	101	102	103	104	104	105	105	105	105	105	106
		81	105	89	67	58	63	93	96	97	99	100	101	102	103	104	104	105	105	105	105	105	106
Yuma, Arizona	May	10	115	95	63			100	105	108	109	113	114	115									
		10	115	95	63	62	62	101	105	108	110	112	113	115	117	118	118	119	119	119	120	120	120
		21	114	94	56	66	68	100	103	105	108	109	111	112	114	114	115	116	116	116	116	116	115
		54	120	93	60	55	59	100	105	[illegible]	110	113	[illegible]	116	118	119	119	120	121	121	122	122	122
	July	10	119	108	81			110	112	113	115	117	118	119									
		10	119	108	81	73	73	112	114	115	116	117	118	119	120	121	121	121	121	122	122	122	122
		21	116	105	73	74	75	107	110	111	112	117	114	115	[illegible]	116	117	117	118	118	118	118	118
		54	118	106	74	67	72	104	107	109	111	113	114	115	117	117	118	118	118	119	119	119	119
	Sept	10	115	103	73			108	110	112	113	114	114	115									
		10	115	103	73	76	76	98	100	111	112	113	114	115	116	116	117	117	117	118	118	118	118
		21	117	101	68	68	70	106	109	111	112	114	115	116	117	118	118	119	119	119	119	120	120
		54	114	101	66	73	76	104	106	107	109	110	111	112	113	113	114	114	114	115	115	115	115

NOTE: For each month, line 1 (underlined figures) gives the actual tabulated temperatures for the various frequencies for the 10-year record. But in line 2, 3 and 4 the temperatures for the various frequency intervals are predicted from the given summarized data for years of record indicated in the "Record" column (i.e., 40-year record, 61-year record).

10/1 means 10 days in 1 month (31 days); 1/50 means 1 day in 50 of the same month (1550 days, 50 years, or 1/1550).

For Formulas for computations, see Appendix D.

Summary and comments

a. The 45 patterns of maximum temperature distribution cover adequately the range essential for satisfactory prediction for summer months.

b. Four items of essential data are generally available for wide areal coverage.

c. The method is satisfactory for manual computation and prediction, and also lends itself readily to machine processing.

d. Visual impressions of areal distribution of maximum temperatures may be secured by mapping processed data.

e. Variables that recur only at long time intervals may not be encompassed within the 10-year coverage. Therefore, predictions from long records are preferable.

f. The validity of the method could probably be improved by integrating into the study more stations, more months, and longer records.

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References

1. Court, Arnold, Summer Temperature in the United States. Monthly Weather Review, Vol. 80, pp. 20-25, February 1952.

2. Lacksy, Earl E., A Graphic Method for Assessing Hourly Temperature Probabilities, Technical Report EP-46, May 1958.

3. -----, A Method for Assessing and mapping the January Daily Minimum Temperatures of Northern North America, Technical Report EP-88, QM Research and Engineering Center, March 1957, Natick, Mass.

4. -----, A Method for Assessing the Amount and Frequency of One-Day Rainfall, Technical Report ES-9, U.S. Army Natick Laboratories, June 1964.

5. U.S. Weather Bureau, *Climatic Summary of the United States*. Bulletin "W", Washington, D.C.

6. U.S. Weather Bureau, Statistical Division, Air Weather Service, Data Control Unit (Ozalid copies).

7. Westbrook, Jane, *High Temperatures at High Altitudes*. QM Research and Engineering Center, Study Report EA-9, January 1958, Natick, Mass.

APPENDIX A

ABBREVIATIONS AND GLOSSARY OF TEMPERATURE TERMS

1. AbMx = Absolute Maximum Temperature:

   The highest temperature ever recorded in a given month at a given station.

2. DMx = Daily Maximum:

   The highest temperature occurring day by day in a given month.

3. DMi = Daily Minimum Temperature:

   The lowest temperatures occurring day by day in a given month.

4. MDMx = Mean Daily Maximum Temperature:

   The average of the DMx's during the period of record.

5. MDMi = Mean Daily Minimum Temperature:

   The average of the DMi's during the period of record.

6. RT = Reduced Temperature:

   Values derived by subtracting the MDMi from the items of essential and frequency data as in Table I.

7. CPT = Converted Predictive Temperatures:

   RT items to be converted to a 100-unit scale as in Table I.

8. CFT = Converted Frequency Temperatures:

   Frequency Temperatures changed to 100-unit scale.

9. CAbMx = Converted Absolute Maximum:

   Reduced AbMx changed to 100 on the 100-unit scale as in Table I.

10. CMDMx = Converted Mean Daily Maximum:

Average of the reduced daily maxima converted to the 100-unit scale as in Table I.

11. CMDMi = Converted Mean Daily Minimum:

Average of the reduced daily minima converted to zero on the 100-unit scale as in Table I.

12. CDMx = Converted Daily Maximum Temperatures:

Reduced temperature values (Table I, line *e*) converted to the 100-unit scale (Table I, line *f*)

13. FPT = Fahrenheit Predictive Temperatures:

CPT values re-converted to Fahrenheit (plus the MDMi) (See 7 and 8 above)

APPENDIX B

RESUME AND SEQUENCE IN THE CONSTRUCTION OF THE MULTIPLE NOMOGRAPH AND THE EQUIVALENT TABLE (TABLE III)

1. Selecting 12 representative weather stations in the United States with requisite daily temperature records for three summer months (May, July, September), through 10-year periods.

2. Tabulating daily maximum temperature frequencies similar to those in Table I (36 in all). This had been done in part by U.S. Air Weather Service, Data Control Unit.

3. Assembling tabulations into frequency summaries (CMDMx and CFT, paired) corresponding to those on Table II.

4. Plotting frequency data (CFT) from (2) and (3) above, thus deriving Basic Section of the Nomograph.

5. Constructing Table III, Basic Section, from the Nomograph.

6. Extrapolation of CPT values in Table III, Basic Section, by use of Skew-Log Probability Scale, thus deriving CPT values in the Extrapolated Section of Table III (underlined figures) and Extrapolated Section of the Nomograph.

7. Computing and entering Identification CMDMx values (numbers not underlined) in Table III.

8. Constructing Nomograph "Duration" Section from CMDMx items derived in (7) above.

9. Validation of method.

10. Solution of problems by use of Nomograph, Appendix C.

11. Solution of problems by use of Table III, Appendix D.

APPENDIX C

FIGURE 2 - THREE-SECTION NOMOGRAPH FOR PREDICTING THE LEVEL AND FREQUENCY OF HIGH TEMPERATURES OF SUMMER

SECTIONS OF THE HIGH TEMPERATURE NOMOGRAPH:

The Basic Section was constructed from tabulated converted daily maximum temperatures secured for May, July and September for 10 years from 12 widely distributed weather stations in the United States (Fig. 1). For construction see Part II. The Extrapolated Section was derived by extrapolation from the Basic Section. For construction see Part III. The "Duration" Section is used to find the 10-year pattern in the Basic or Extrapolated Section to be used when the basic abbreviated record is longer than 10 years. For its construction see Part IV.

EXPLANATION OF NOMOGRAPH:

The horizontal lines (36 to 80, left margin) represent CMDMx temperatures; the vertical lines (10 to 128), represent CPT temperatures; the curved sloping lines (Basic and Extrapolated Sections) represent prediction values for indicated intervals of time from 25 days in 1 month (25/31 days) to 1 day in 100 months, e.g., 100 Mays (100 yrs or 1/3100 days); sloping lines in the "Duration" Section are designed to find the 10-year equivalent for any length of abbreviated record up to 100 years.

USING THE NOMOGRAPH: Example A - 10-Year Record. "Duration" Section not involved.

Given: In May at Shreveport, during a 10-year period:
AbMx, 93F MDMx, 83F MDMi, 62F

Required: What May maximum may be equaled or exceeded -
3 days in a year, i.e., 3 days in 1 May, 3/31?
1 day in 3 years (3 Mays) 1/93? In 30 years, 1/930?
In 70 years, 1/2170?

Solution:

a. Find CMDMx

Formula: $$CMDMx = \frac{100\ (MDMx - MDMi)}{AbMx - MDMi}$$

(Substituting:) $$\frac{100\ (83 - 62)}{93 - 62} = 67.7 \text{ or } 68 \text{ (rounded)}$$

CMDMx 68 is the pattern for predicting DMx temperature for May at Shreveport.

b. Find required CPT's (converted predictive temperatures for required time intervals)

Method: Follow CMDMx 68 from the left margin of the nomograph (Sign δ) to prediction lines and thence upward to respective CPT's (as Nomograph, line 68, Example A)

3/31, CPT 88	1/93, CPT 95
1/930, CPT 104	1/2170, CPT 107

c. Reconvert to °F

Formula: DMx associated with given frequencies:

$$\frac{\text{CPT (AbMx - MDMi}}{100} + \text{MDMi}$$

(Substituting CPT's from b above:)

Probable 1-day maximum temperature -

3/31 (3 May days in 1 year) $\frac{88\ (93 - 62)}{100} + 62 = 89\text{F}$

1/93 (1 May day in 3 years) $\frac{95\ (93 - 62)}{100} + 62 = 91\text{F}$

1/930 (1 May day in 30 years) $\frac{104\ (93 - 62)}{100} + 62 = 94\text{F}$

1/2170 (1 May day in 70 years) $\frac{107\ (93 - 62)}{100} + 62 = 95\text{F}$

Therefore the expected May maximum temperature at Shreveport will be 89F or more 3 days in a year; 91F in 3 years; 94F in 30 years; 95F in 70 years.

USING THE NOMOGRAPH: Example B - 70-Year Record. "Duration" Section needed for solution.

Given: In September* in Shreveport, during a 71-year record:
AbMx, 105F MDMx, 89F MDMi, 67F

Required: What September daily maximum temperature may be expected:

*See note associated with Table II.

5 days in 1 year, i.e., 5 days in 1 Sept, 5/30?
1 day in 5 years (5 Septembers) 1/150?
1 day in 10 years (10 Septembers) 1/300?
1 day in 40 years, 1/1200? (to agree with other 30-day figs.)

Solution:

a. **Find the 70-Year CMDMx**

For 1a (as Example A) $CMDMx = \dfrac{100\ (MDMx - MDMi)}{AbMx - MDMi}$

(Substituting:) $\dfrac{100\ (89 - 67)}{105 - 67} = 57.9$ or 58 (rounded)

b. **Find the 10-year (record) equivalent CMDMx**

Method: Follow arrows and signs (ø) on vertical line 70 (70 years) in "Duration" Section of Nomograph downward to CMDMx 58 thence left and upward on nearest sloping line to 10-yr vertical line (accentuated). This intersection is on CMDMx 63. Use the CPT values of CMDMx 63 for predicting on the 10-year nomograph.

c. **Find associated CPT values**

Method: On CMDMx 63, in the Basic and Extrapolated Sections, find the place where it crosses the required curved prediction lines,* follow this up to the CPT value at top of graph. These CPT's are:

5/31, 82	1/155, 97	1/310, 100
1/1240, 106;	1/2170, 108;	1/2790, 109

d. **Find AbMx for 10 years** (i.e., equaled or exceeded in 10 Septembers)

Method: In the Extrapolated Section follow CMDMx 63 to the 70-yr predictive line, thence upward to CPT 108. The 70-yr AbMx (105F) is CPT 108 on the 10-yr nomograph

Formula: $10\text{-yr Mx} = \dfrac{100\ (70\text{ yr AbMx} - 70\text{ yr MDMi})}{70\text{ yr CPT, CMDMx } 63} + MDMi$

$$100\ \frac{(105 - 67)}{108} + 67 = 102F$$

*See footnote Section 14. See "Example B", far left on the Nomograph

e. <u>Reconvert to °F as in Example A</u>

Formula (DMx associated with given frequencies):

$$\frac{\text{CPT (10-yr AbMx - 70-yr MDMi)}}{100} + \text{MDMi}$$

Substituting CPT's from <u>c</u> above:

Predicted DMx 5/31 $\quad \frac{82\ (102 - 67)}{100} + 67 = 96\text{F}$

Predicted DMx, 1/155 $\quad \frac{97\ (102 - 67)}{100} + 67 = 101\text{F}$

Predicted DMx 1/310 $\quad \frac{100\ (102 - 67)}{100} + 67 = 102\text{F}$

Predicted DMx 1/1240 $\quad \frac{106\ (102 - 67)}{100} + 67 = 104\text{F}$

Predicted DMx 1/2170 $\quad \frac{108\ (102 - 67)}{100} + 67 = 105\text{F}$

Predicted DMx 1/2790 $\quad \frac{109\ (102 - 67)}{100} + 67 = 106\text{F}$

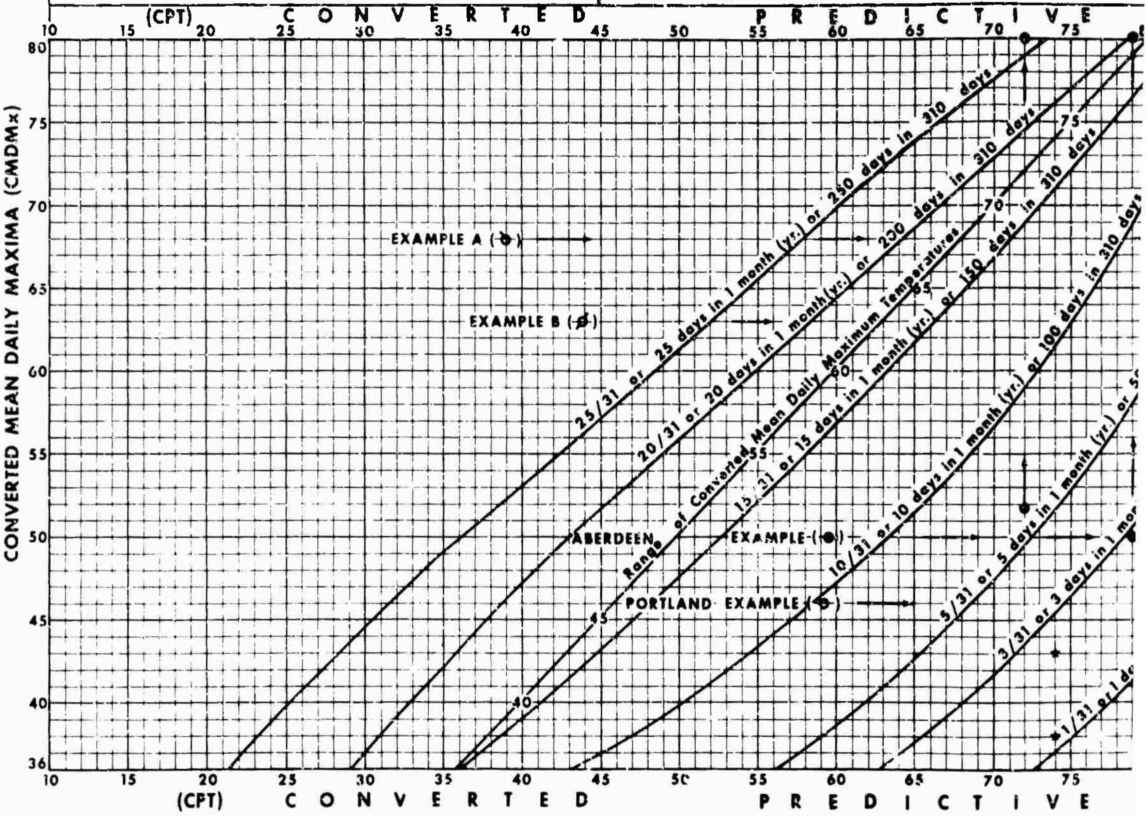
MULTIPLE NOMOGRAPH FOR PREDIC

MAXIMUM TEMPE

TO PREDICT FROM 10-YEAR

Basic Section From 25 Days In a Given Month Up

Constructed From Actual Frequency Distribution Of Daily Maxima At
In Representative Areas In The U.S.A.



<u>Explanation of General Symbols:</u>

★ Stars in the Basic Section represent paired converted temperature values(CM

▲ Triangles in the Extrapolated Section represent CPT values extrapolated fron
and used to construct the 1/620 prediction curved line.

● Dots in the "Duration" Section for line "xy", identifying the CMDMx 60 (on
values to use in place of 12 different patterns of longer or shorter records(1,

Examples A and B are discussed in Appendix C.

Examples Aberdeen and Portland are discussed in the text, Sections 6 and

Figure 2

APH FOR PREDICTING FREQUENCIES OF DAILY

AXIMUM TEMPERATURES

ROM 10-YEAR RECORD ONLY

a Given Month Up To 10 Years

Distribution Of Daily Maxima At 12 Stations
Areas In The U.S.A.

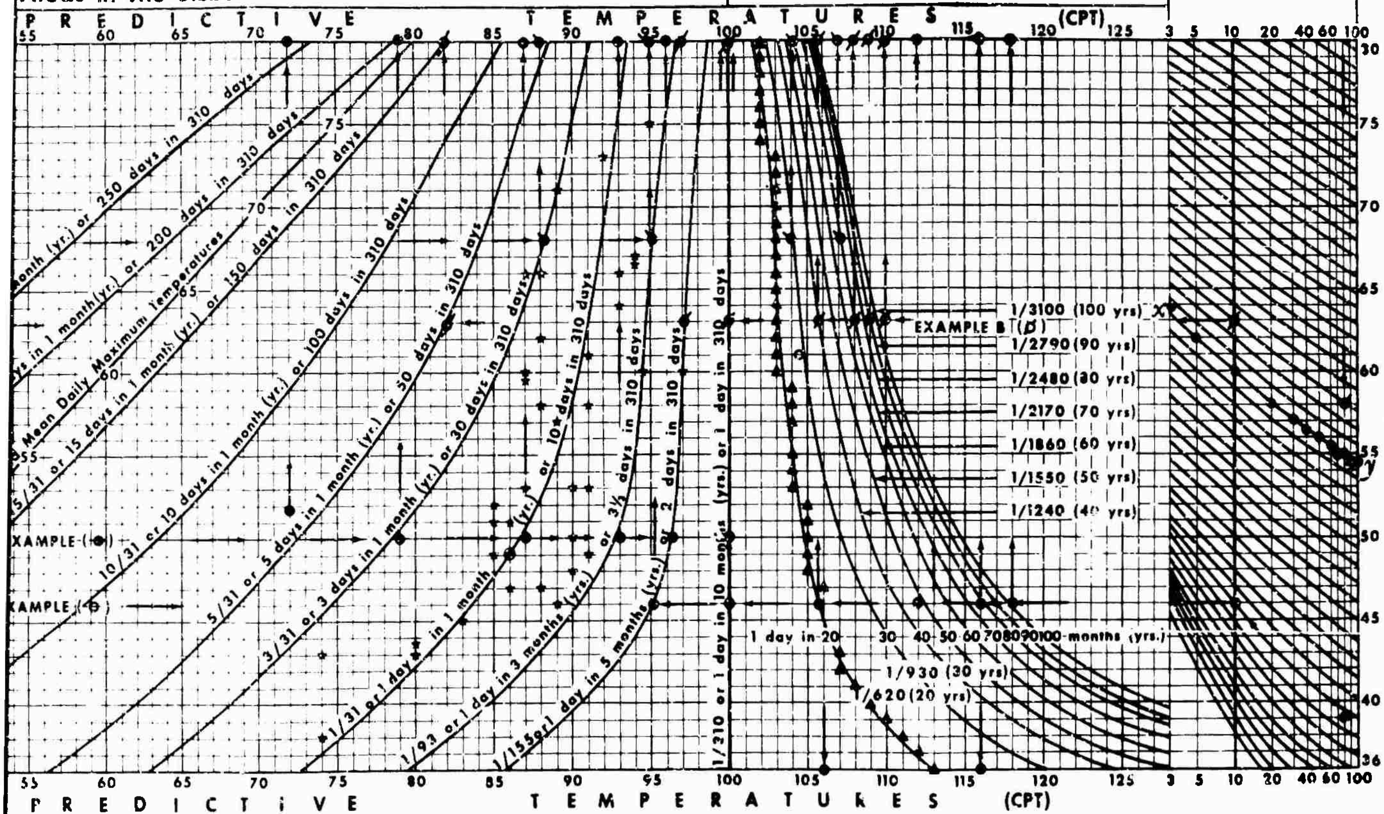
Extrapolated Section
Increments, 20 to 100 years

Extrapolated From
Basic Section

Predicting From
Long Records
Up to 100 Years

Duration Section

TO FIND THE 10 YEAR
CMDMx EQUIVALENTS



verted temperature values(CMDMx and associated CFT values, Table II) for the 1/31 curved prediction line.

CPT values extrapolated from the CPT trends in the 45 CMDMx predictive patterns in the Basic Section, ved line.

dentifying the CMDMx 60 (on the 10-year vertical accentuated line) represent predictive pattern of CPT of longer or shorter records(1/93 to 1/3100). See text, Section 12.

C.

d in the text, Sections 6 and 14, respectively.

2

Figure 2

APPENDIX D

TABLE III - PATTERNS OF CONVERTED MEAN DAILY MAXIMUM TEMPERATURES (CMDMx) WITH ASSOCIATED CONVERTED PREDICTION TEMPERATURE VALUES CPT KEYED TO A 100-UNIT SCALE AND A 10-YEAR RECORD, AND USED TO CALCULATE THE PROBABLE LEVEL AND FREQUENCY OF DAILY MAXIMUM TEMPERATURES

Explanation and Use:

1. This is a table of constant values taken from the Multiple Nomograph (Fig. 2). It is presumed to cover (approximately) the various patterns of daily maximum temperature distributions through the 5 or 6 summer months. The table is constructed to resemble somewhat the nomograph from which the data are taken.

2. There are 45 Converted Mean Daily Maxima (CMDMx 36 to 80, left column) and associated with each in the rectangular cells on the same line are (numbers underlined) converted predictive temperatures (CPT) which probably will be equaled or exceeded in the time span specified at the top of the columns. For example, CPT values 35 in column 25/31 is associated with CMDMx 50 pattern. The other CPT's (underlined numbers) in this pattern are: 20/31, 44; 15/31, 52; 10/31, 63; 5/31, 72; etc., to 1/310, 100 and 1/3100, 115 (19 CPT underlined values associated with each CMDMx (36 to 80, left margin).

3. Notice that the table centers on the accentuated double column (1/310) 1 day in 10 years, 310 days, because the nomograph was constructed from 36, 10-year (monthly) records. For this reason, the 10-year Daily Maximum is always 100-units on the converted scale. Note that the CMDMi is always reduced to zero (0) in this study.

4. Using Table III for Predictions. Example A - 10-Year Record.* (Only underlined numbers on the table are involved).

Given: In May at Aberdeen, Maryland, during a 10-year period: AbMx, 95F   MDMx, 74F   MDMi, 53F

Required: What May maximum temperature may be equaled or exceeded in 5 years? 30 years? 60 years? 90 years?

Solution:

a. Find CMDMx

Formula: $$\text{CMDMx} = \frac{100\ (\text{MDMx} - \text{MDMi})}{\text{AbMx} - \text{MDMi}}$$

*This example was also discussed in section 6, using Nomograph

(Substituting:) $\frac{100\ (74 - 53)}{95 - 53} = 50$

CMDMx 50 is the May pattern for predicting DMx temperatures at Aberdeen

b. Find required CPT's (converted predictive temperatures for required time intervals)

Method: Follow CMDMx 50 from left margin to each required time interval - indicated in column heading at top of nomograph. These CPT's are:
For 5 yrs, 96 — 30 yrs, 107
60 yrs, 112 — 90 yrs, 114

c. Reconvert to °F

Formula: (DMx associated with given frequency)

$$\frac{\text{CPT}\ (\text{AbMx} - \text{MDMi})}{100} + \text{MDMi}$$

(Substituting CPT's from b above:)

Predicted 5-yr Max (1/155) $\frac{96\ (95 - 53)}{100} + 53 = 93\text{F}$

Predicted 30-yr Max (1/930) $\frac{107\ (95 - 53)}{100} + 53 = 98\text{F}$

Predicted 60-yr Max (1/1860) $\frac{112\ (95 - 53)}{100} + 53 = 100\text{F}$

Predicted 90-yr Max (1/2790) $\frac{114\ (95 - 53)}{100} + 53 = 101\text{F}$

Therefore the expected May maximum temperature at Aberdeen in 5 years will equal or exceed 93F. In 30 yrs, 98F. In 60 yrs, 100F and in 90 yrs 101F.

5. Using Table III. Example B - 67-Year Record. (Numbers not underlined on the table are involved).

Given: In July at Kansas City, Missouri, during a 67-year record:
AbMx: 112F MDMx, 92F MDMi, 71F

Required: What July maximum temperature may be equaled or exceeded 1 day in: 10 years? 3 years? 40 years? 60 years? 90 years?

Solution:

a. Find the 70-year record CMDMx

Formula: $\text{CMDMx} = \dfrac{100\ (\text{MDMx} - \text{MDMi})}{\text{AbMx} - \text{MDMi}}$

(Substituting:) $\dfrac{100\ (92 - 71)}{112 - 71} = 51.2$ or $\underline{51}$ (rounded)

b. Find the 10-yr (record) equivalent to CMDMx 51 in 70-yr column

Method: Follow down the 70-year column to the number 51 (not underlined). This is found on the CMDMx 56 line. Therefore, the CMDMx 56 pattern of CPT values will be used for prediction.

c. Find the required CPT's (converted predictive temperatures for required time intervals) using CMDMx 56 pattern.

Method: As in Example A above. These CPT's are:
For 10 yrs, 100 For 3 yrs, 94 For 40 yrs, 107
For 60 yrs, 110 For 90 yrs, 111

d. Find the 10-yr (record) predicted Absolute Maximum

Formula: $\dfrac{100\ (70\text{ yr AbMx} - 70\text{ yr MDMi})}{70\text{ yr CPT, CMDMx } 56^*} + \text{MDMi}$

*(This value is in the 70-yr column, CMDMx56 line of table. That is, the 70-yr AbMx is CPT 110 on the 10-yr table)

(Substituting:) $\dfrac{100\ (112 - 71)}{110} + 71 = 108°F$

e. Reconvert to °F (using 108°F as AbMx)

Formula: DMx associated with given frequencies:

$$\frac{\text{CPT}\ (10\text{-yr AbMx} - 70\text{-yr MDMi})}{100} + \text{MDMi}$$

(Substituting CPT's from
$\underline{c}$ above:)

Predicted 3-yr maximum $\frac{94\ (108 - 71)}{100} + 71 = 106F$

Predicted 40-yr maximum $\frac{107\ (108 - 71)}{100} + 71 = 111F$

Predicted 60-yr maximum $\frac{110\ (108 - 71)}{100} + 71 = 112F$

Predicted 90-yr maximum $\frac{111\ (108 - 71)}{100} + 71 = 112F$

TABLE III. TABULAR EQUIVALENT OF THE NOMOGRAPH

CMD Mx	Frequency in Days / Frequency in % / Years of Record	25/31 80.6 1	20/31 64.5 1	15/31 48.4 1	10/31 32.3 1	5/31 16.1 1	3/31 9.68 1	1/31 3.22 1	1/93 1.075 3	1/155 .645 5	1/310 .323 10	1/620 .161 20	1/930 .108 30	1/1240 .0806 40	1/1550 .0645 50	1/1860 .0538 60	1/2170 .0461 70	1/2480 .0403 80	1/2790 .0358 90	1/3100 .0323 100	CMD Mx
		Constructed from 10-Years Actual Frequencies									Constructed by Extrapolation from 10-Year Frequency Records										
80		72	79	82	85 94	88 91	91 88	94 85	97 83	99 81	100 80	102 79	103 78	104 77	104 77	105 76	105 76	106 76	106 76	106 76	80
79		70	78	81	84 94	88 90	91 87	93 85	96 83	99 80	100 79	102 78	103 77	104 76	104 76	105 75	105 75	106 75	106 75	106 75	79
78		69	76	80	84 93	87 90	90 86	93 84	96 81	98 79	100 78	102 77	103 76	104 75	104 75	105 74	105 74	106 74	106 74	106 74	78
77		68	75	79	83 93	87 89	90 85	93 83	96 80	98 78	100 77	102 76	103 75	104 74	104 74	105 73	105 73	106 73	106 73	107 72	77
76		66	74	79	83 92	87 88	90 84	93 82	96 79	98 77	100 76	102 75	103 74	104 73	104 73	105 72	105 72	106 72	106 72	107 71	76
75		65	73	78	82 91	87 87	90 83	93 81	96 78	98 76	100 75	102 73	103 73	104 72	105 71	105 71	106 71	106 71	107 70	107 70	75
74		63	72	77	82 90	86 86	90 82	93 80	96 77	98 75	100 74	102 72	103 72	104 71	105 70	106 70	106 70	106 70	107 69	107 69	74
73		62	70	76	81 90	86 85	89 82	93 79	96 76	98 74	100 73	103 71	103 71	104 70	105 69	106 69	106 69	107 68	107 68	107 68	73
72		60	69	75	81 89	86 84	89 81	92 78	95 76	98 73	100 72	103 70	103 70	104 69	105 68	106 68	106 68	107 67	107 67	107 67	72
71		59	68	74	80 89	85 83	89 80	92 77	95 75	98 72	100 71	103 69	104 68	105 68	105 67	106 67	107 66	107 66	107 66	108 66	71
70		58	67	73	80 88	85 82	89 79	92 76	95 74	98 71	100 70	103 68	104 67	105 67	106 66	106 66	107 65	107 65	108 65	108 65	70
69		57	66	72	79 87	84 82	88 78	92 75	95 73	98 70	100 69	103 67	104 66	105 66	106 65	106 65	107 64	107 64	108 64	108 64	69
68		57	65	71	78 87	84 81	88 77	92 74	95 72	98 69	100 68	103 66	104 65	105 65	106 64	107 64	107 63	107 63	108 63	108 63	68
67		56	64	70	78 86	84 80	88 76	91 73	95 71	98 68	100 67	103 65	104 64	105 64	106 63	107 63	107 62	108 62	108 62	109 62	67
66		55	64	69	77 86	83 79	87 76	91 72	95 70	98 67	100 66	103 64	104 63	105 63	106 62	107 62	107 61	108 61	108 61	109 61	66
65		55	62	68	76 85	83 78	87 75	91 71	95 69	98 66	100 65	103 63	104 62	105 62	106 61	107 61	108 60	108 60	109 60	109 60	65
64		54	61	67	76 84	82 78	86 74	91 70	95 68	97 66	100 64	103 62	104 61	106 61	106 60	107 60	108 59	108 59	109 59	110 59	64
63		52	59	66	75 84	82 77	86 73	91 69	95 67	97 65	100 63	103 61	105 60	106 60	107 59	108 58	108 58	108 58	109 58	110 58	63
62		50	57	65	74 83	81 76	86 72	91 68	95 66	97 64	100 62	103 60	105 59	106 59	107 58	108 57	108 57	109 57	109 57	110 57	62
61		49	56	64	74 83	81 75	86 71	90 67	95 65	97 63	100 61	103 59	105 58	106 58	107 57	108 56	108 56	109 56	110 56	110 56	61
60		48	56	63	73 82	80 75	85 71	90 66	94 64	97 62	100 60	103 58	105 57	106 57	107 56	108 55	109 55	109 55	110 55	110 55	60
59		46	55	62	72 82	80 74	84 70	90 65	94 63	97 61	100 59	104 57	105 56	106 56	108 55	109 54	109 54	110 54	110 54	110 54	59
58		45	53	61	71 82	79 73	84 69	90 64	94 62	97 60	100 58	104 56	105 55	107 55	108 54	109 53	109 53	110 53	110 53	111 52	58
57		43	51	60	70 81	78 73	83 69	90 63	94 61	97 59	100 57	104 55	106 54	107 53	108 53	109 52	110 52	110 52	111 51	111 51	57
56		41	50	59	69 81	78 72	83 68	89 62	94 60	97 58	100 56	104 54	106 53	107 52	109 52	110 51	110 51	111 51	111 50	112 50	56

70	56	57	73	80 88	85 82	89 79	92 76	92 74	98 71	100 70	103 68	104 67	105 67	106 66	106 66	107 65	107 65	108 65	108 65	70
69	57	56	72	72 87	84 82	88 79	92 75	92 73	98 70	100 69	103 67	104 66	105 66	106 65	106 65	107 64	107 64	108 64	108 64	69
68	57	55	71	78 87	84 81	86 77	92 74	95 72	98 69	100 68	103 66	104 65	105 65	106 64	107 64	107 63	107 63	108 63	108 63	68
67	56	54	70	78 86	84 80	88 76	91 73	95 71	98 68	100 67	103 65	104 64	105 64	106 63	107 63	107 62	108 62	108 62	109 62	67
66	55	54	69	77 85	83 79	87 76	91 72	95 70	98 67	100 66	103 64	104 63	105 63	106 62	107 62	107 61	108 61	108 61	109 61	66
65	55	52	68	76 85	83 78	87 75	91 71	95 69	98 66	100 65	103 63	104 62	105 62	106 61	107 61	108 60	108 60	109 60	109 60	65
64	54	51	67	76 84	82 78	86 74	91 70	95 68	97 66	100 64	103 62	104 61	106 61	106 60	107 60	108 59	108 59	109 59	110 59	64
63	52	59	66	75 84	82 77	86 73	91 69	92 67	97 65	100 63	103 61	105 60	106 60	107 59	108 58	108 58	108 58	109 58	110 58	63
62	50	57	65	74 83	81 76	86 72	91 68	95 66	97 64	100 62	103 60	105 59	106 59	107 58	108 57	108 57	109 57	109 57	110 57	62
61	49	56	64	74 83	81 75	86 71	90 67	95 [illegible]	97 63	100 61	103 59	105 58	106 58	107 57	108 56	108 56	109 56	110 56	110 56	61
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57	43	51	60	70 81	78 73	83 69	90 63	94 61	97 59	100 57	104 55	106 54	107 53	108 53	109 52	110 52	110 52	111 51	111 51	57
56	41	50	59	69 81	78 72	83 68	89 62	94 60	97 58	100 56	104 54	106 53	107 52	109 52	110 51	110 51	111 51	111 50	112 50	56
55	40	49	58	68 81	77 71	82 67	89 62	94 59	97 57	100 55	104 53	106 52	107 51	109 51	110 50	111 50	111 50	112 49	112 49	55
54	39	48	57	67 81	76 71	82 66	89 61	94 58	97 56	100 54	104 52	106 51	107 50	109 50	110 49	111 49	112 48	112 48	113 48	54
53	38	47	56	66 80	75 70	81 65	88 60	94 57	96 55	100 53	104 51	106 50	108 49	110 49	111 48	112 47	112 47	113 47	113 47	53
52	37	46	54	65 80	74 70	81 64	88 59	93 56	95 54	100 52	105 50	107 49	108 48	110 48	111 47	112 46	113 46	113 46	114 46	52
51	36	45	52	64 80	73 70	80 64	87 59	93 55	96 53	100 51	105 49	107 48	108 47	110 47	111 46	113 45	113 45	114 45	114 45	51
50	35	44	52	63 79	72 69	79 63	87 58	93 54	96 52	100 50	105 48	107 47	108 46	111 45	112 45	113 44	114 44	114 44	115 43	50
49	34	43	51	62 79	71 69	78 63	86 58	92 53	96 51	100 49	105 46	107 46	109 45	111 44	112 44	114 43	114 43	115 43	115 42	49
48	33	42	50	61 79	70 69	77 62	85 56	92 52	96 50	100 48	105 45	108 45	110 44	111 43	113 43	114 42	115 42	115 42	116 41	48
47	32	41	48	60 78	69 68	76 62	84 56	91 51	96 49	100 47	106 44	108 44	110 43	112 42	113 42	115 41	115 41	116 41	117 40	47
46	31	40	47	59 78	68 68	75 61	83 55	91 50	95 48	100 46	106 43	109 43	111 41	112 41	114 41	115 40	116 40	117 39	118 39	46
45	31	40	47	58 78	67 67	74 61	82 55	90 50	95 47	100 45	106 42	109 41	111 40	113 40	115 39	116 39	117 39	118 38	119 38	45
44	29	39	46	57 77	66 66	72 60	81 54	89 49	94 47	100 44	106 41	110 40	112 39	114 39	116 38	117 38	118 37	119 37	120 37	44
43	27	37	45	56 77	65 66	72 60	80 54	88 49	93 46	100 43	107 40	111 39	113 38	115 38	117 37	118 36	119 36	120 36	121 36	43
42	25	35	44	55 76	64 66	71 59	79 53	86 48	92 46	100 42	107 39	112 38	114 37	116 36	118 36	119 36	120 35	122 34	123 34	42
41	23	33	42	54 76	63 65	70 59	78 53	85 48	91 45	100 41	108 38	113 36	115 36	117 35	119 35	121 34	122 34	124 33	125 33	41
40	22	32	41	53 76	62 65	69 58	77 52	84 47	90 44	100 40	109 37	114 35	116 35	119 34	121 33	123 33	124 32	126 32	127 32	40
39	20	30	40	52 75	61 64	68 57	76 51	83 47	89 44	100 39	110 36	115 34	117 34	121 32	123 32	125 31	126 31	128 31	130 30	39
38	18	28	39	51 75	60 63	67 57	75 51	82 46	88 43	100 38	111 34	116 33	119 32	123 31	125 30	128 30	129 30	131 29	138 29	38
37	16	26	38	50 74	59 63	66 56	74 50	81 45	87 43	100 37	112 33	118 31	121 31	125 30	127 28	131 28	132 28	134 28	136 27	37
36	15	25	36	49 74	58 62	65 55	73 49	80 45	86 42	100 36	113 32	120 30	124 29	127 28	131 28	134 27	136 27	138 26	140 26	36

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